The Phenomenal APG-63

USAF/McDONNELL F-15A
THE EYES OF THE EAGLE

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INTRODUCTION

To the Aircrews and Radar Maintenance personnel of the Air Force F-15 Eagle:

Congratulations! You've been selected to fly and maintain one of the most advanced fighters equipped with the most advanced radar in the world today. It's a system designed to maximize your skills—to help you execute each and every mission as successfully as possible and to provide air superiority anywhere anytime.

The phenomenal APG-63 radar is truly the Eyes of the Eagle. This pulse doppler radar functions with long range, all-aspect, clutter-free detection capabilities that have never been available in previous radars. This new capability comes from design concepts that incorporate power levels, beam widths, scan patterns, mode options and signal processing techniques which are new to most aircrews and maintenance people.

The APG-63 radar, like many other things, has its peculiarities or what we like to call PHENOMENA (or PHENOS). A phenomenon will occur or appear occasionally because of doppler effect, signal resolution, synthetic target displays, scan patterns, signal interference, or perhaps pilot functions which cause something to happen or be observed which may not be understood completely.

This booklet is designed to help you understand them—the peculiarities (or PHENOS) that may be encountered. Typical PHENOS, the anticipated squawks, and the relevant designed capabilities that apply to each are illustrated and discussed on the following pages. Another look at what can be done and what can't be done with this radar may further the understanding of radar write ups and corrective actions required for the Eyes of the Eagle.

Additional features are being implemented in the APG-63 Radar. As these added capabilities are fielded, changes to this publication will be issued.

Let us introduce you to . . .

. . . to complain, to protest —

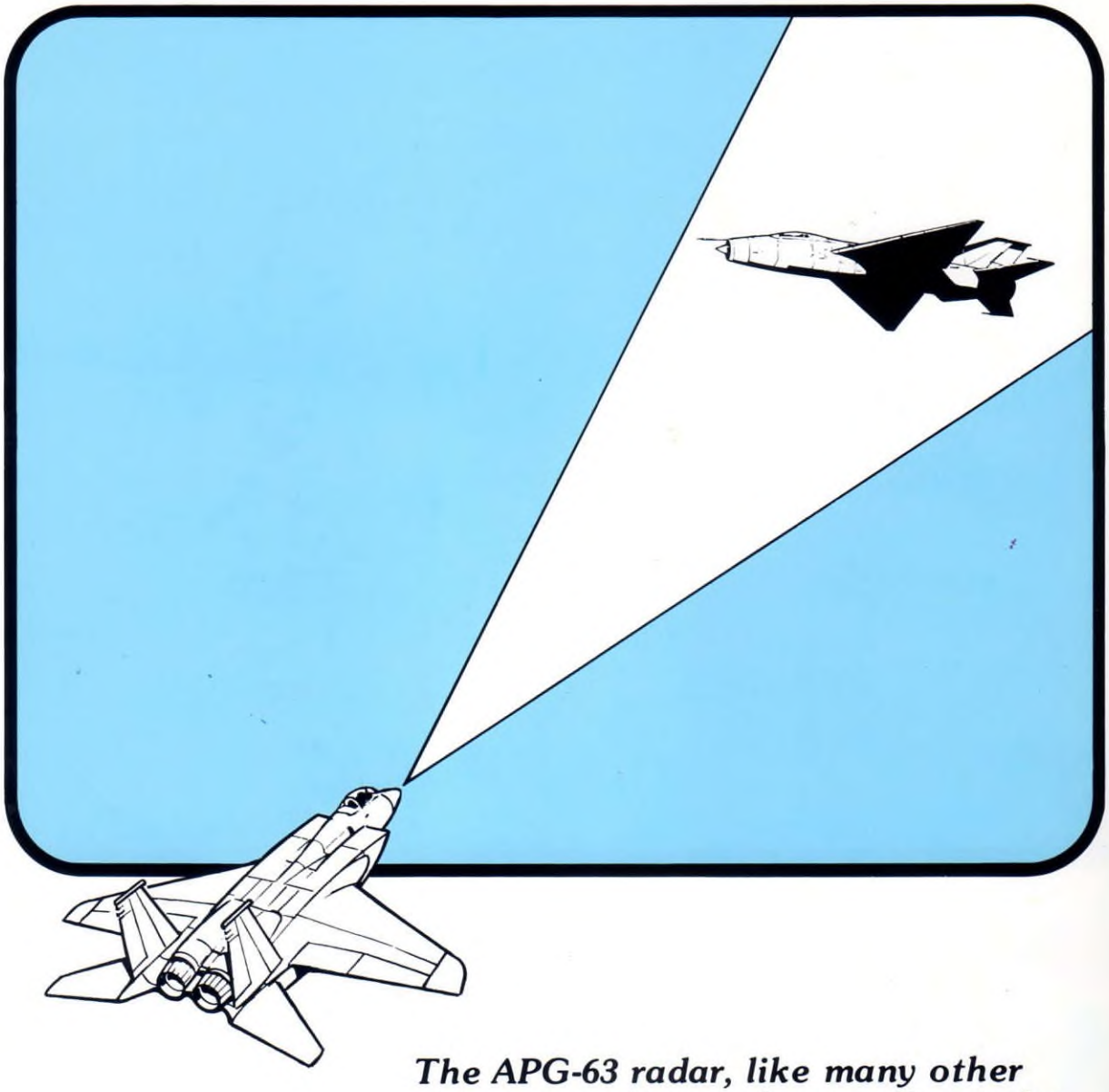
I'm SQUAWK, the guy you see or don't see when whatever it is you're looking for is or isn't there when it should or shouldn't be — I think?? —

. . . a fact, occurrence or circumstance observed, something that impresses the observer —

I'm PHENO, the guy that's peculiar to the APG-63 — I'm the one you're just getting to know — without knowledge of me, you may incorrectly interpret some of my peculiarities as abnormal performance.

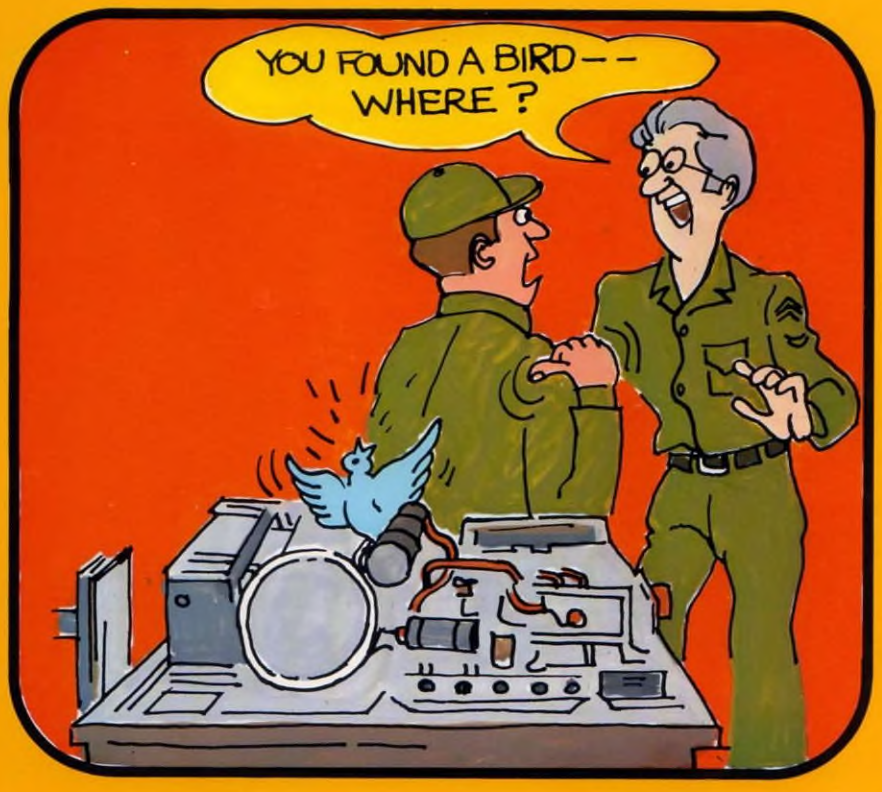
. . . a detailed precise mechanization of something —

I'm DESIGN, the guy we all know because that is what we intended the APG-63 to do.

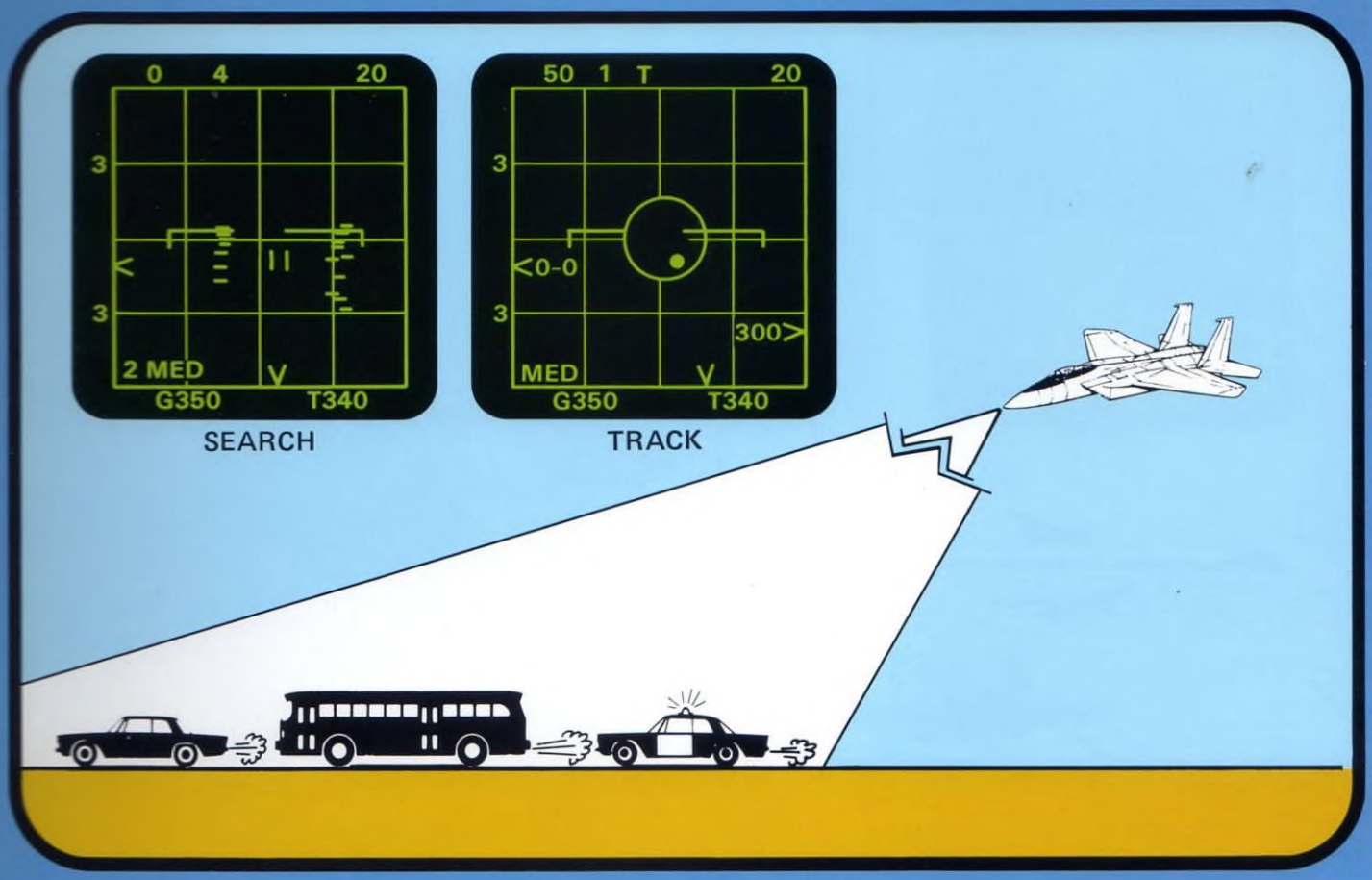


The APG-63 radar, like many other things, requires understanding to be utilized to its fullest. It seems appropriate, now that the F-15 Eagle is becoming operational in large numbers, that the Eyes of the Eagle become more familiar to the people who now use them.

The following pages illustrate some of the things that happen to the Eyes of the Eagle when its vision is normal, but when its own PHENOMENA at times present blurred or unclear pictures to the viewer.



FALSE TARGETS



Squawk

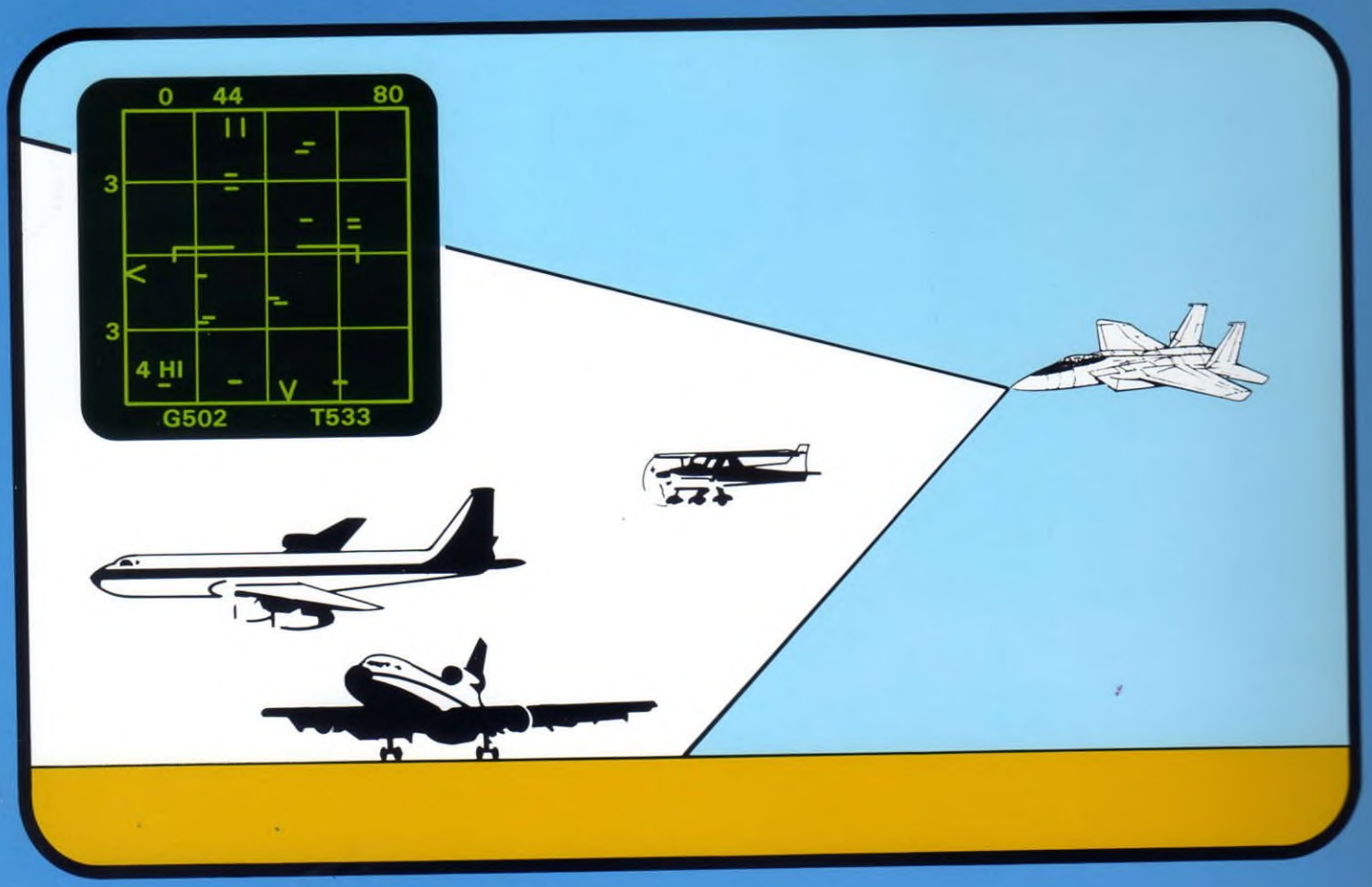
The Radar displayed many false targets in LRS or SRS Mode. No airborne traffic was reported or visually encountered in the area. No detections were noted in the VS (Velocity Search) Mode.

Pheno

Ground moving targets will sometimes be detected and painted on the scope (primarily in MED PRF) in an irregular fashion resembling freeways or railways. If a successful lock-on is made, the indicated Vc will be 40 - 50 kts from the Eagle's ground speed.

Design

The Radar is designed to inhibit detection and display of ground moving traffic such as highway and railway traffic. However, to ensure a minimum velocity blind zone for airborne detections, certain large and/or high speed ground traffic can exceed the inhibit threshold and be displayed. If, during other periods of the flight and during look-up conditions, the display appears clear of false detections and no BIT fails exist, then the chances are that the radar is functioning normally.



Squawk

The radar displayed many false targets at various ranges and azimuths.

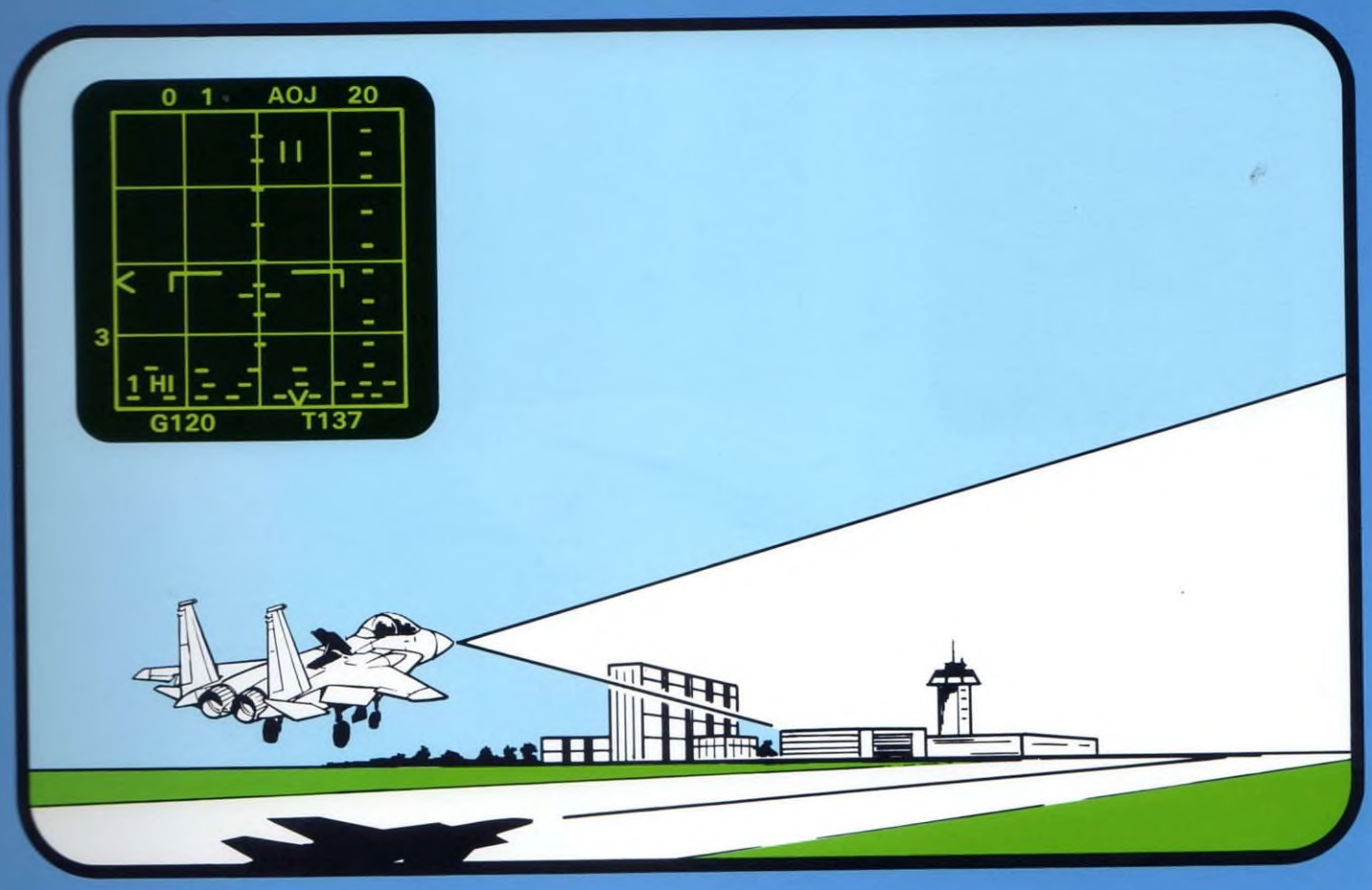
Pheno

Heavy air traffic, be it military or civil, can present a confused VSD. Intermittent type detections can be the result of aspect angle changes and can be interpreted as false alarms. When you had a saturated display temporarily—check—were you in the vicinity of high density air traffic? Remember that the illuminated volume can be tremendous - e. g.; 6700 square miles, 46,000 feet altitude with 4 bar, 120° scan, 80 NM range selected.

Design

The Radar is designed to detect all airborne targets at all aspect (except beam aspect) angles. It is especially sensitive to nose aspect targets closing at relatively high speed. Detection ranges are directly related to target size and aspect angle. Cluttered displays can be expected in high density traffic areas.

NOT F



Squawk

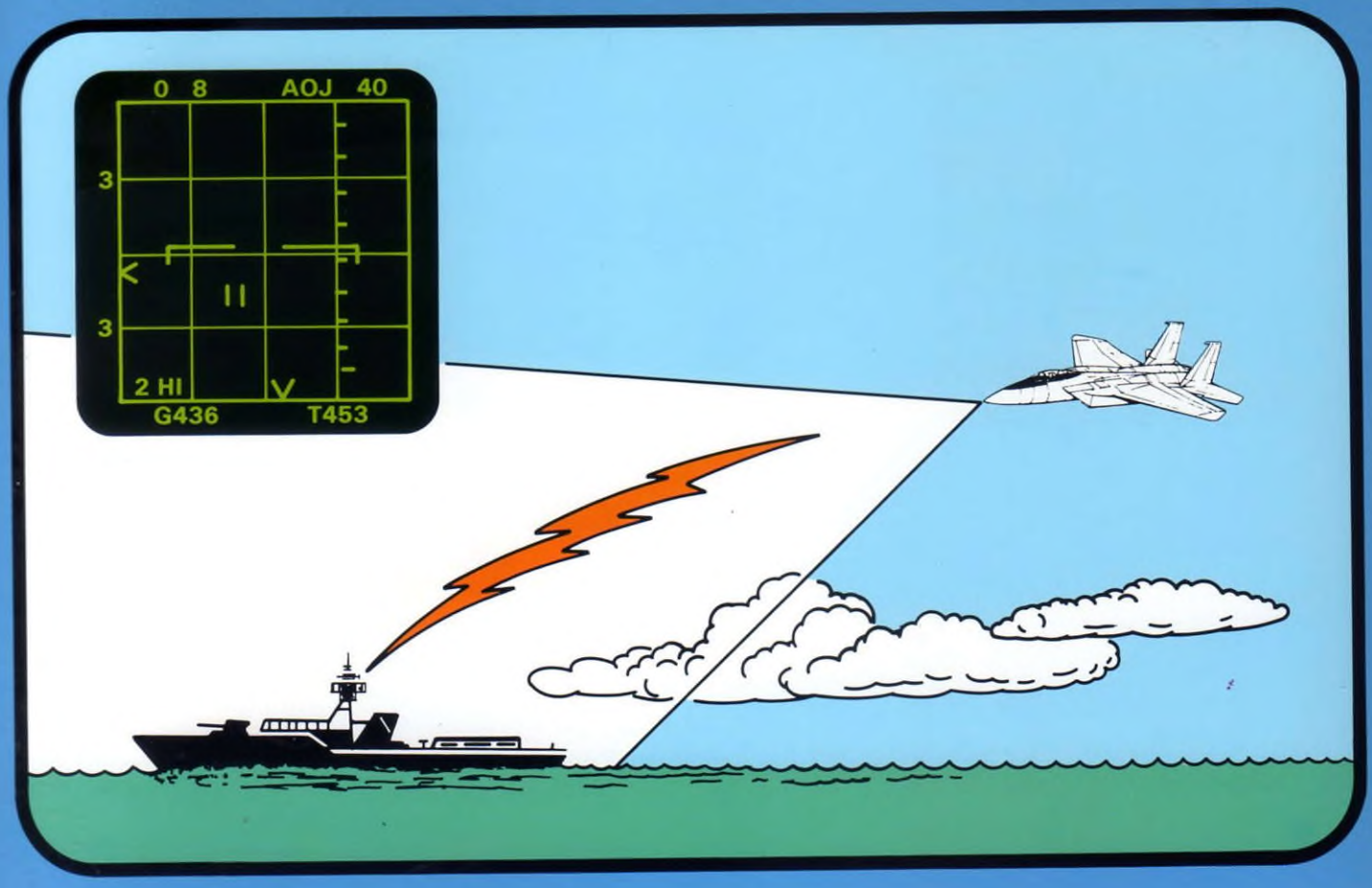
The radar display saturates with false target blips and false AOJ bars at very low altitudes, particularly during landing and takeoff.

Pheno

During takeoffs and landings or during low altitude flights you can completely saturate the system as the dynamic range of the radar is overcome by the heavy ground return. This is normal and the system is operating normally. False targets and AOJ (angle-on-jam) indications will clear as altitude is obtained.

Design

The radar has a very large dynamic range (capable of processing large variations in returned signal energy) but a limit does exist. When these limits are exceeded by extremely large signal returns, such as those encountered at very low altitudes (buildings, mountains, etc.), the radar set saturates, resulting in spurious detections which are displayed, and at times also interpreted as jamming; thus the resulting AOJ bars. Usually, on take-off, as the F-15 flies through 500 ft AGL, the target buildup will reduce unless the antenna is pointing down.



Squawk

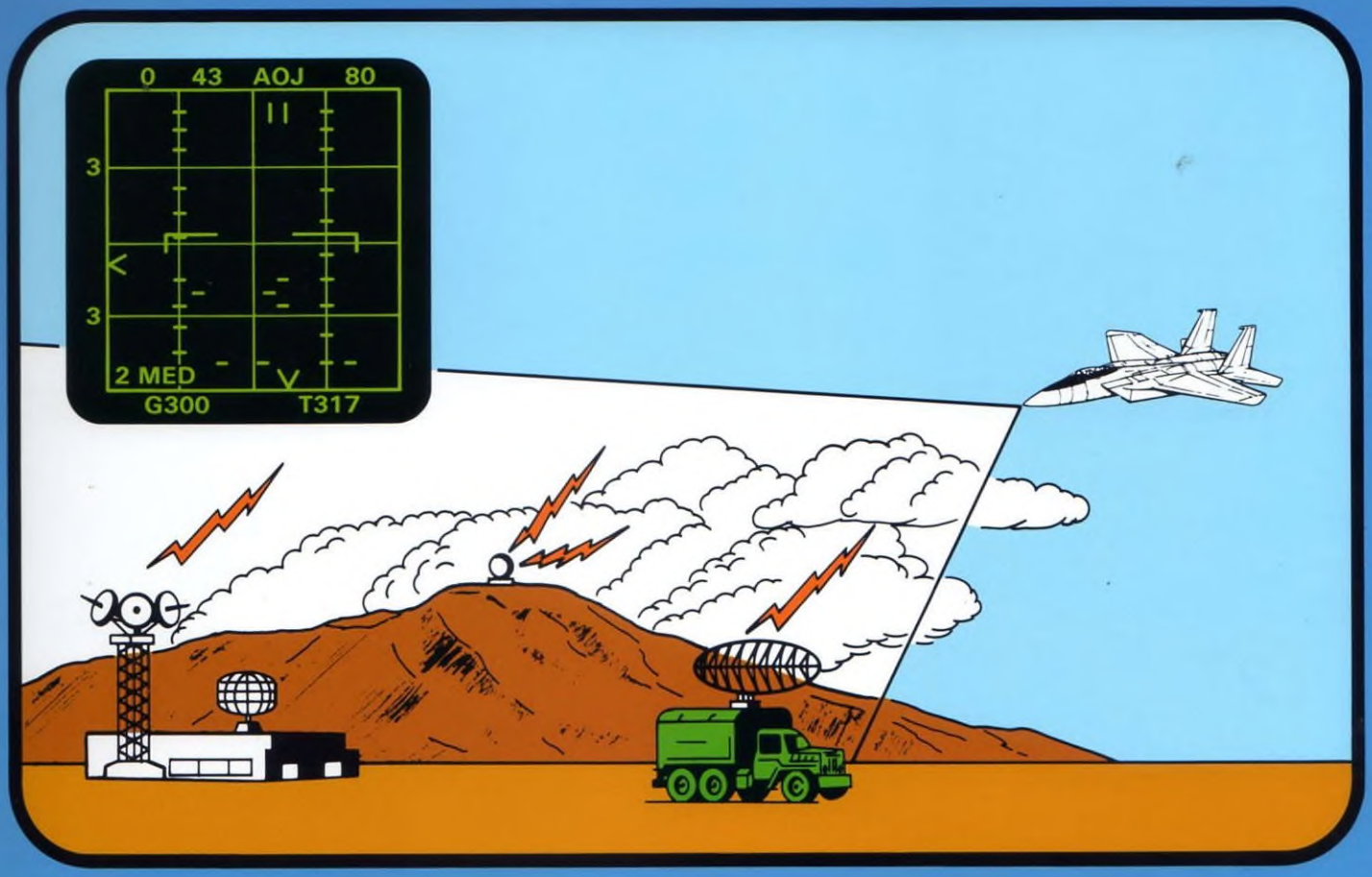
Display indicated a specific false jamming source, consistent in bearing. Target did not have a jamming source.

Pheno

An ECM (Electronic Countermeasure) device unknown to the operator could be creating legitimate AOJ. If this is the case, the AOJ will be very restricted in angle and an established track will indicate HOJ (home-on-jam) with very accurate pointing angles to the ECM source.

Design

The radar set is designed to detect and counter all interfering radiators.



Squawk

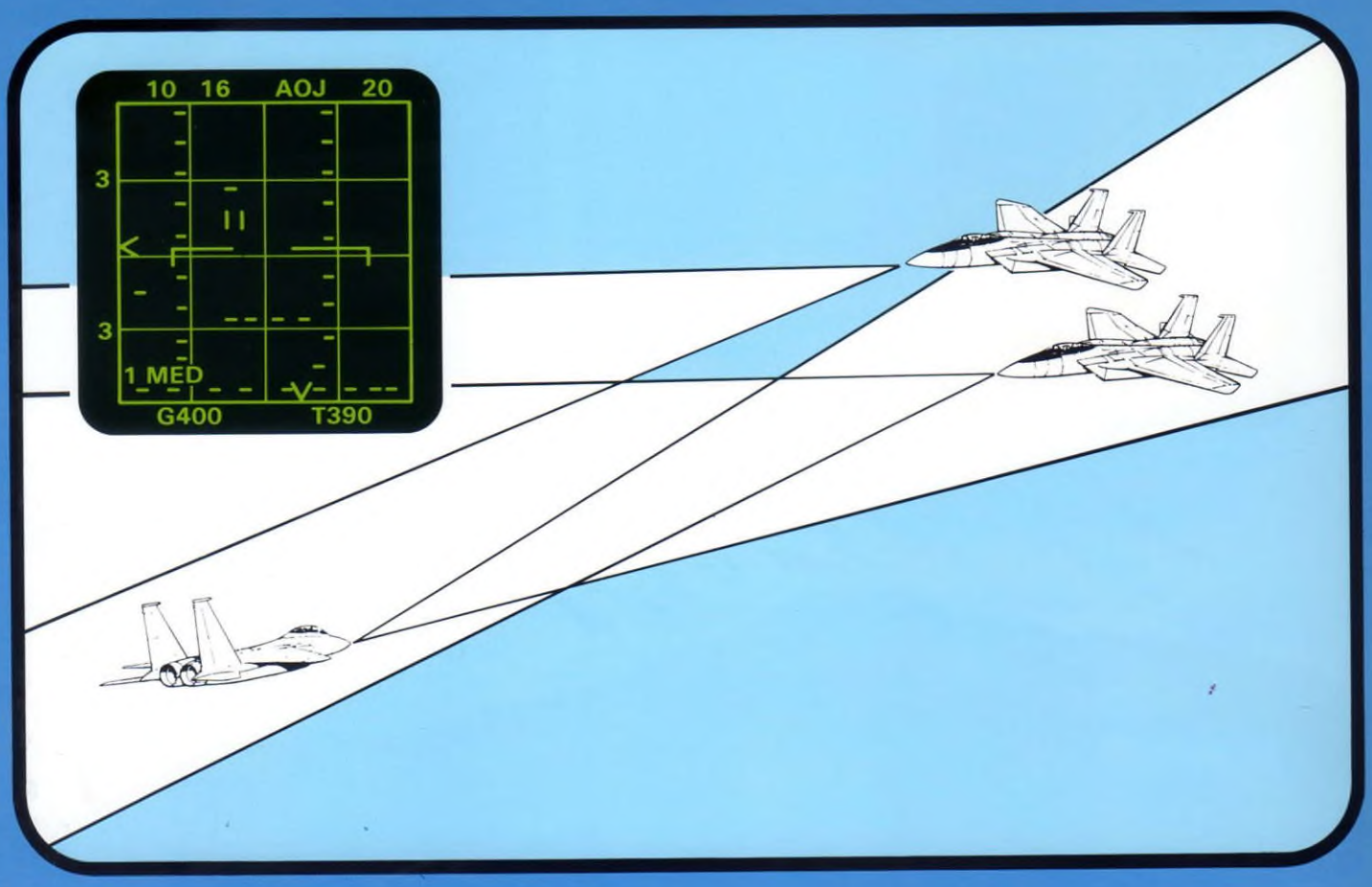
The display indicated various false random jamming sources. Could not detect target.

Pheno

When operating in the same area with other radars operating on X-band frequencies the scope can show many blips, making identification of a specific target nearly impossible. Before writing the radar set up, check indications on different headings, both look-up and look-down. The APG-63 is probably operating normally if jamming indications no longer are apparent.

Design

An extremely large air/ground space volume can be illuminated by the radar set. Any interference detected in this volume by the APG-63 will be transformed to false alarms and AOJ indications to the pilot on the VSD.



Squawk

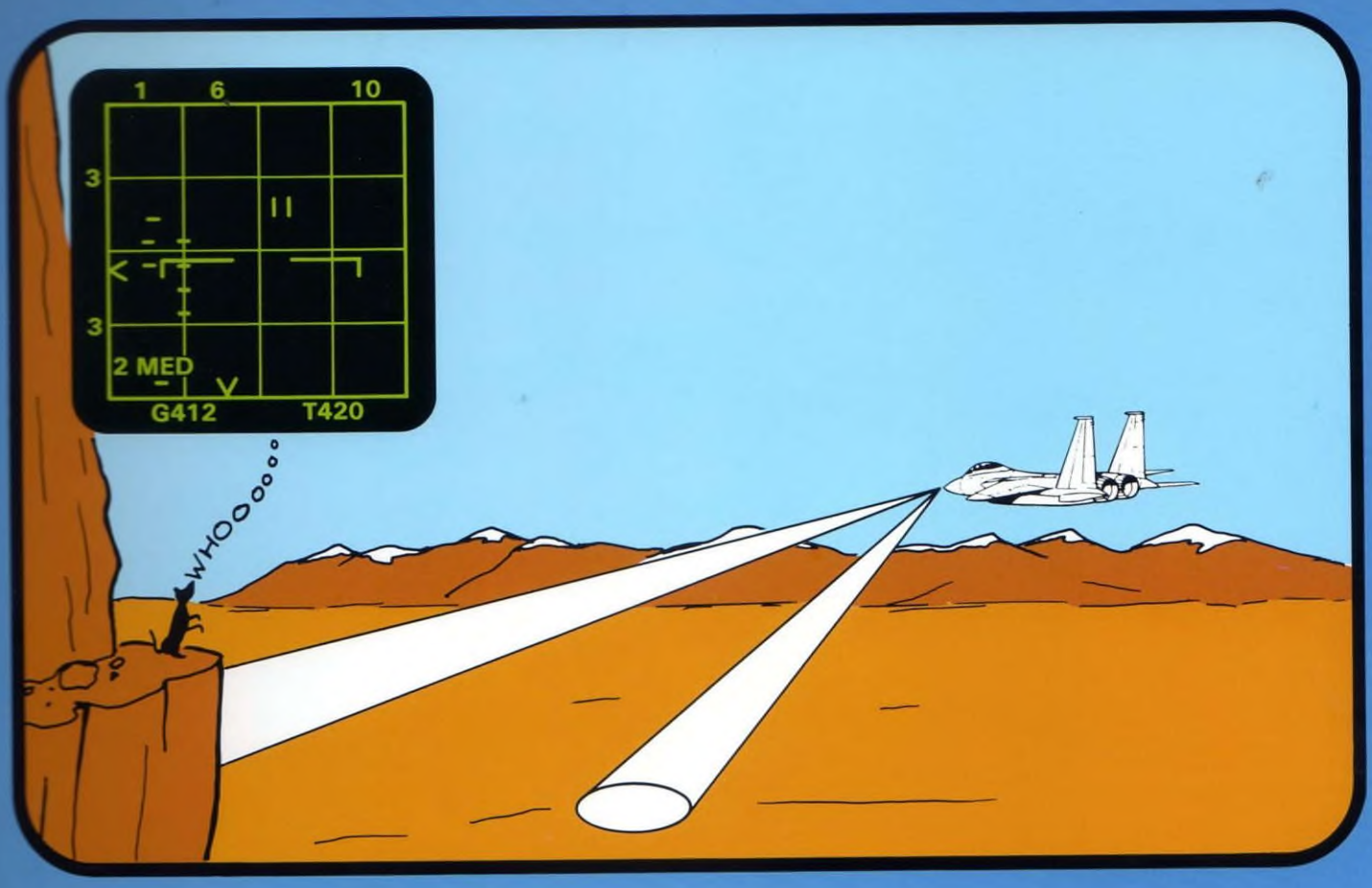
False targets and AOJ on VSD; could not detect target.

Pheno

Formation flying or having other F-15's attacking with operating radars can illuminate you with radar energy causing false alarm and AOJ indications on the scope. Aircraft within a formation should coordinate operating channel selection to reduce mutual interference. If the interference can be eliminated by channel selection, the APG-63 is probably operating normally.

Design

Each APG-63 has six operating frequency channels that can be selected within a frequency band. Each aircraft can have one of three frequency bands (A, B, C) installed. These design features make it possible to reduce the probability of creating mutual interference as well as increase the probability of countering mutual interference.



Squawk

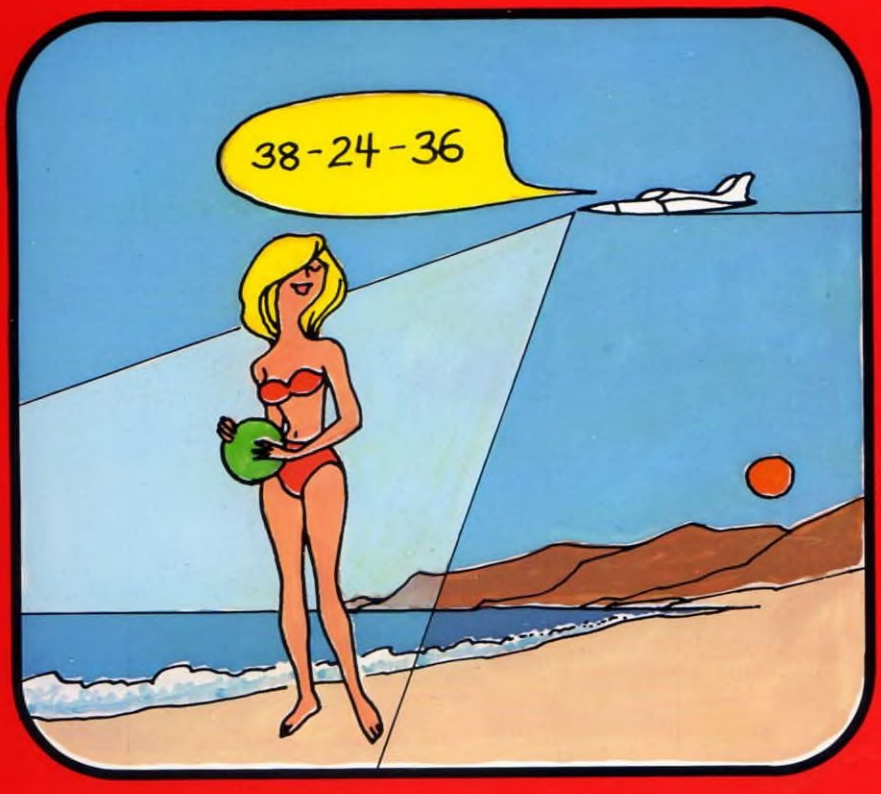
Encountered the display of random false targets located at a general range/azimuth. Flight altitude seemed sufficient to preclude false alarms from saturation effects.

Pheno

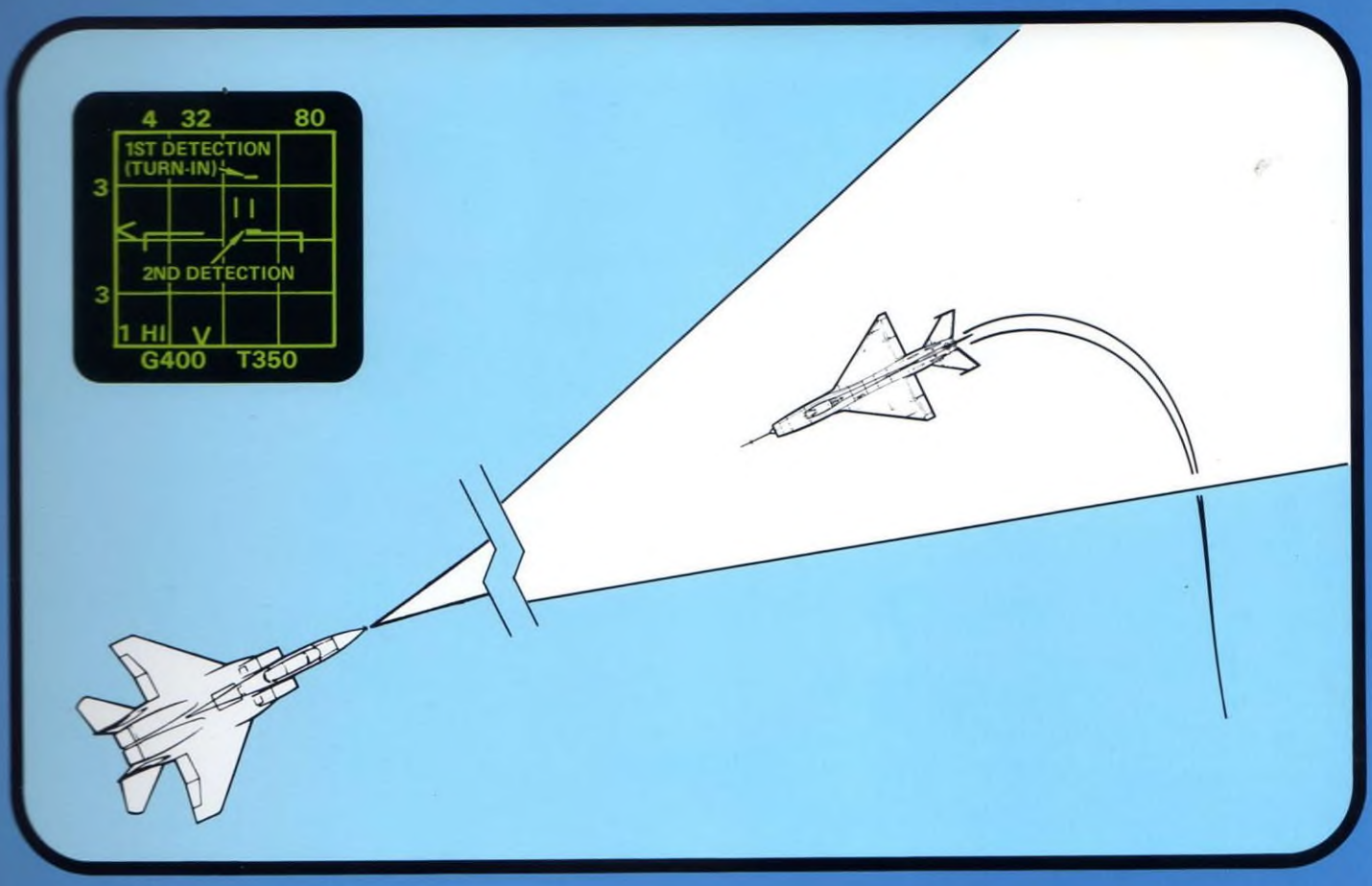
There are times when you paint blips that are caused when your antenna beam experiences an abrupt change in the main lobe from some sharp ground reflectivity. Remember, are these blips recurring all during the mission? If not, this may be the cause.

Design

An abrupt change in ground clutter reflectivity will result in the same saturation effects which occur at very low altitude. Thus spurious returns may occur when the main beam strikes near-range mountains or large buildings surrounded by relatively flat terrain.



DETECTION



Squawk

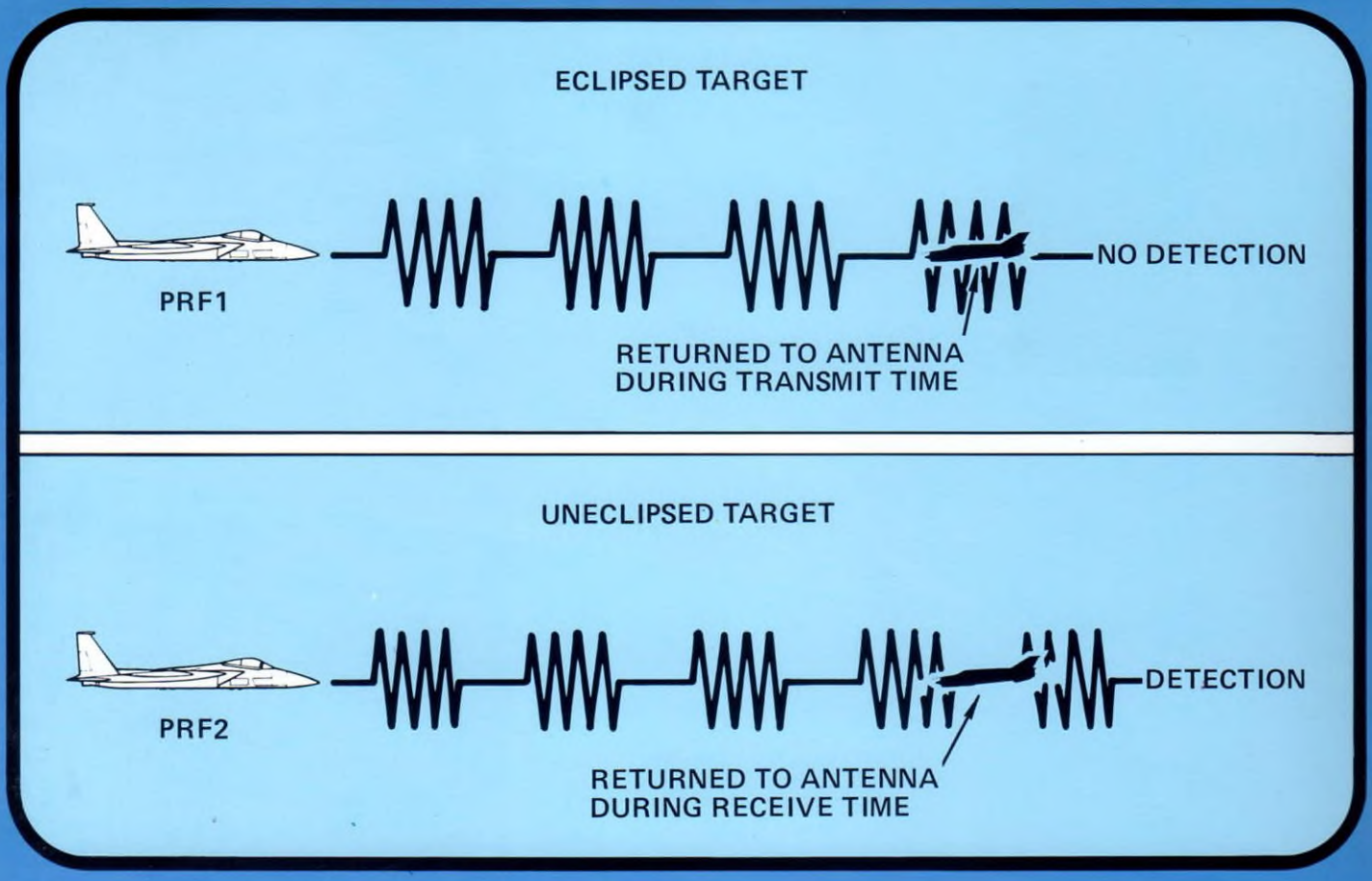
Detected the target on an initial turn-in range but lost him until close in.

Pheno

Target reflectivity is important to detection range. Many times as the target turns in to begin a run the wings will present a large cross-section to the radar. As the target settles out on a different aspect angle it is possible for the cross-section to decrease drastically and detection will not occur until the range closes.

Design

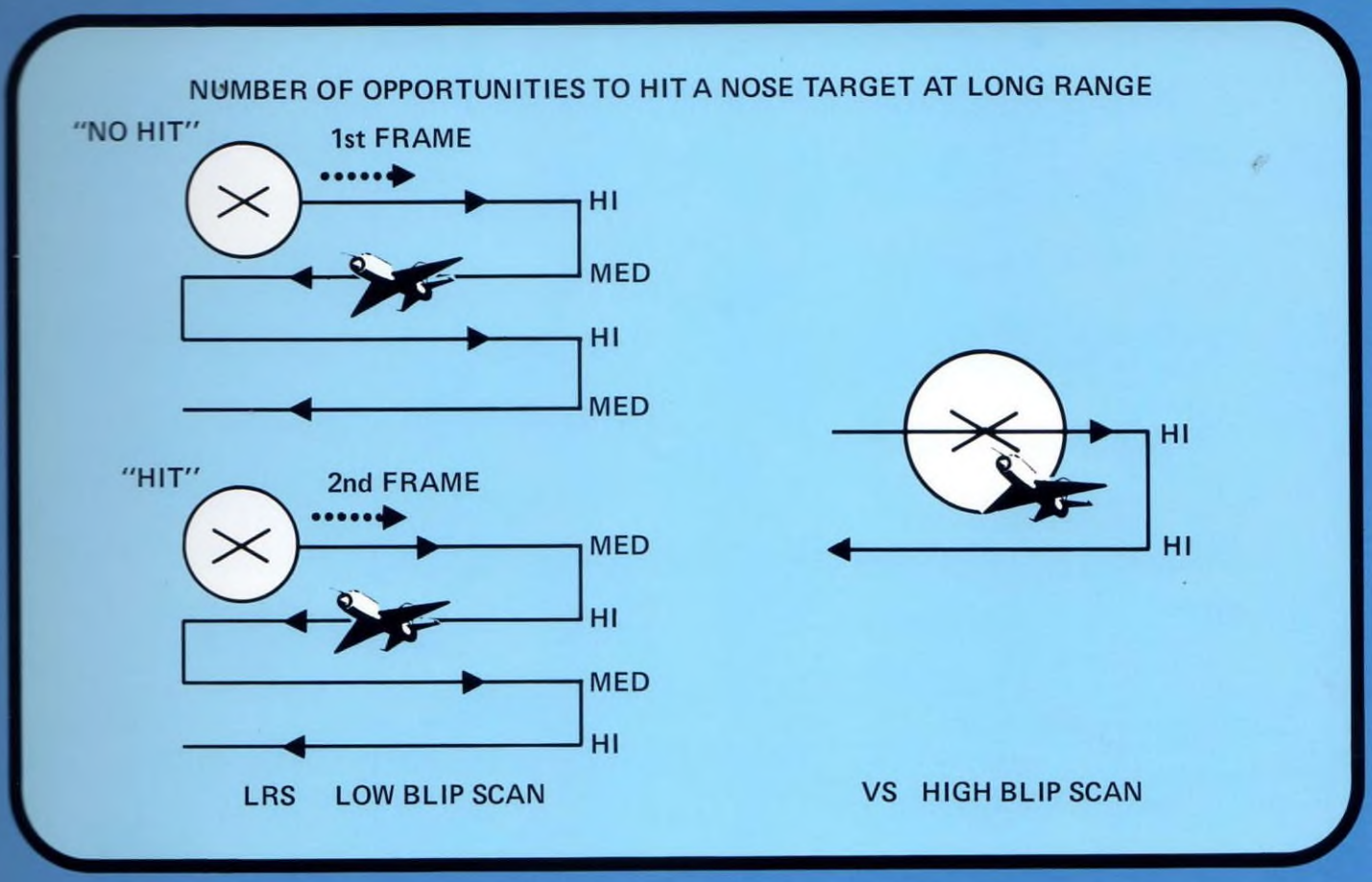
Detection sensitivity is directly related to target size/cross-section which in turn varies considerably for the same target depending on the instantaneous aspect angle.



Could not detect target from X to Y miles after good initial detection at Z miles.

Target detections can become intermittent or fade completely due to range eclipsing even though the target is well within detectable range limits. Break locks may also occur due to these changes. Even though the radar appears troublesome during these happenings, it is functioning normally.

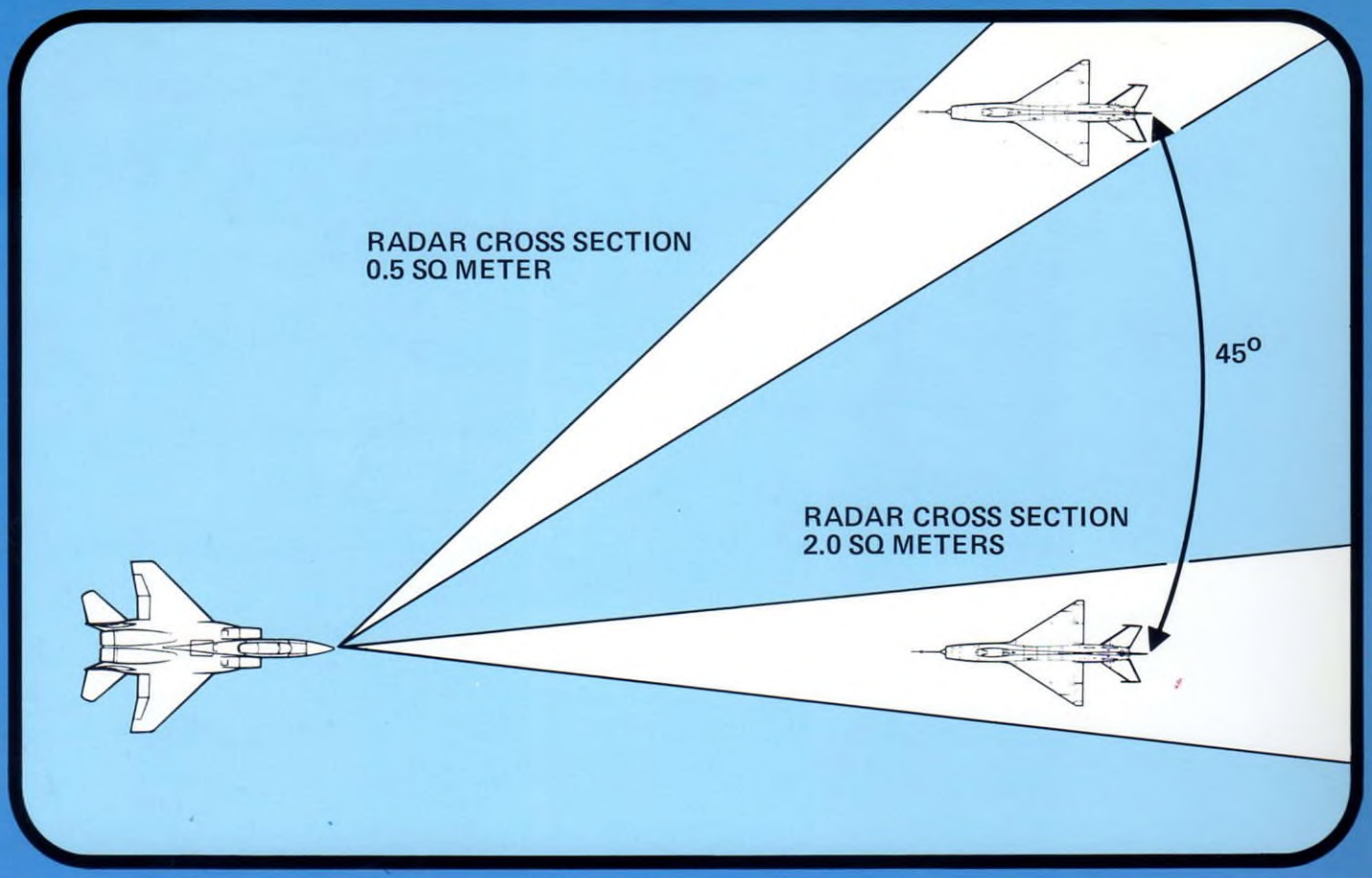
Target eclipsing occurs when the target echo from a previously transmitted pulse returns to the antenna at the exact moment that the radar transmits another pulse. The target is not detected because the receiver must be gated off during the transmit time. The effects of eclipsing in the APG-63 are minimized by the automated selective use of different transmitted pulse repetition rates. This design, in conjunction with the high probability of changing flight dynamics, limits the occurrences and duration of the eclipsing fades.



Squawk *Sensitivity was low today. Radar was weak in all modes.*

Pheno Detection range does in fact vary and the circumstances dictate the norm. Remember, every detection with the same radar will not always be at the same range. Detection of a given size target will vary depending on aspect, closing speed, and scan volume selected. It is possible for a target to close as much as 4 to 5 miles between opportunities to detect. A good rule of thumb is: The smaller the scan volume, the longer the detection will be, providing the target is in the scan volume.

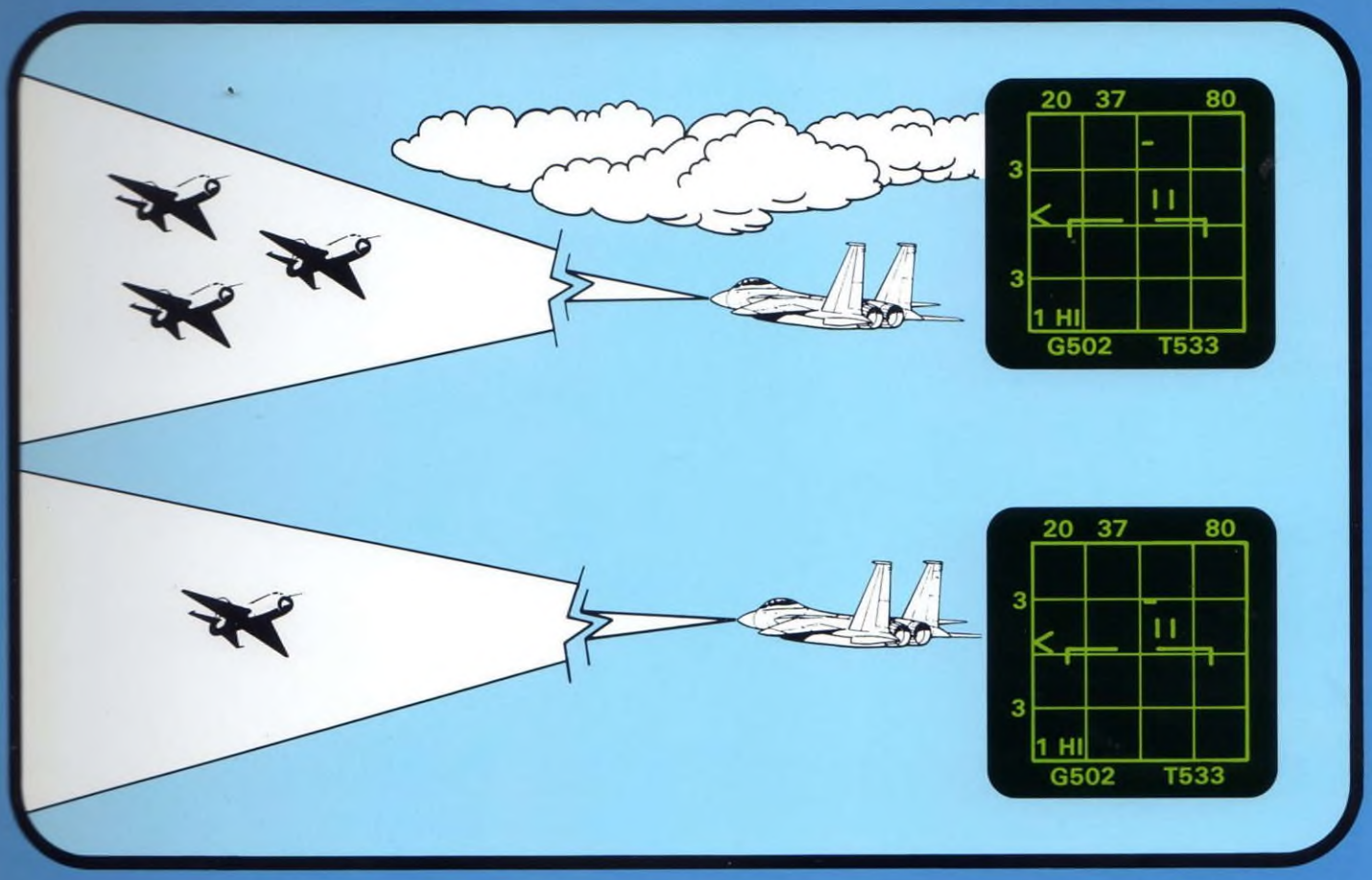
Design The LRS mode is interleaved with HPRF and MPRF on a bar-to-bar basis. HPRF is optimized for nose aspect detections; however, on a given size target, a HPRF nose aspect detection will occur at a much greater range (a factor of 2 to 1 or greater) than a MPRF tail aspect detection.



Detection range was only x miles on 2nd pass. Got him at x+15 on first pass. Radar is deteriorating.

The radar target size is sensitive to the aspect angle and the strength of the radar signal return will vary with changing azimuth location. Generally, changes in the radar reflectivity follow the size of the silhouette that the eye might see modified somewhat strangely when applied to a radar wavelength. A drastic reduction in radar reflectivity can occur at certain aspect angles due to target surface related characteristics (angles/edges) which do not affect the visual silhouette. These strange changes in relative reflectivity are different and highly dependent on the type of target.

Variations in aspect angle produce variations in detection range. The APG-63 cannot compensate for these variations. A variety of detection ranges on a given target may be expected.



Squawk

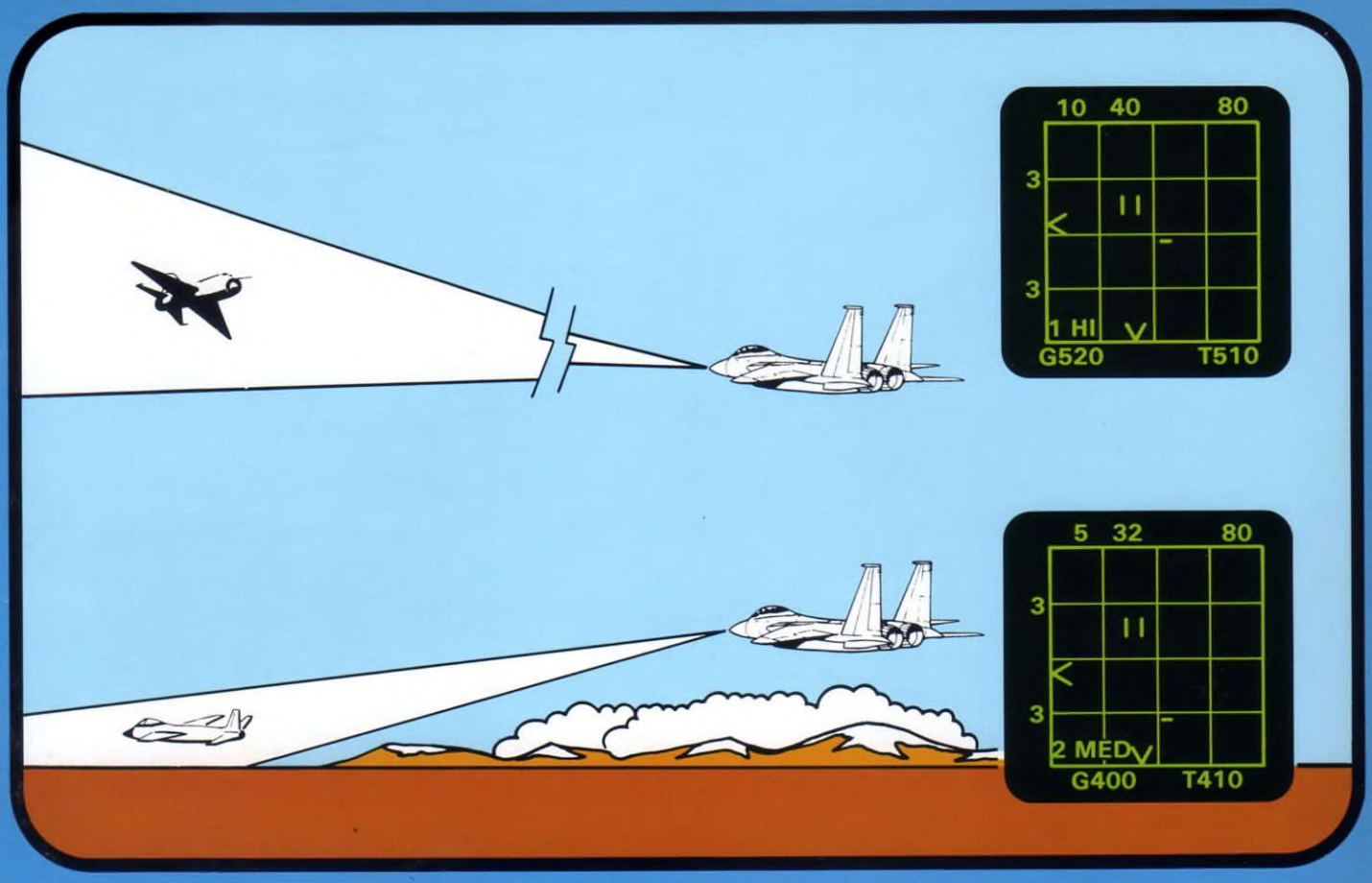
Detection range is degrading; detected a target formation at x +10 miles on first pass, only x miles on re-attack against single target.

Pheno

Recalling that the larger the target size the greater the detection range, we find that multiple targets versus a single target will increase the apparent detection range considerably. So a radar that suddenly appears weak after longer range detections against multiple targets is really functioning properly.

Design

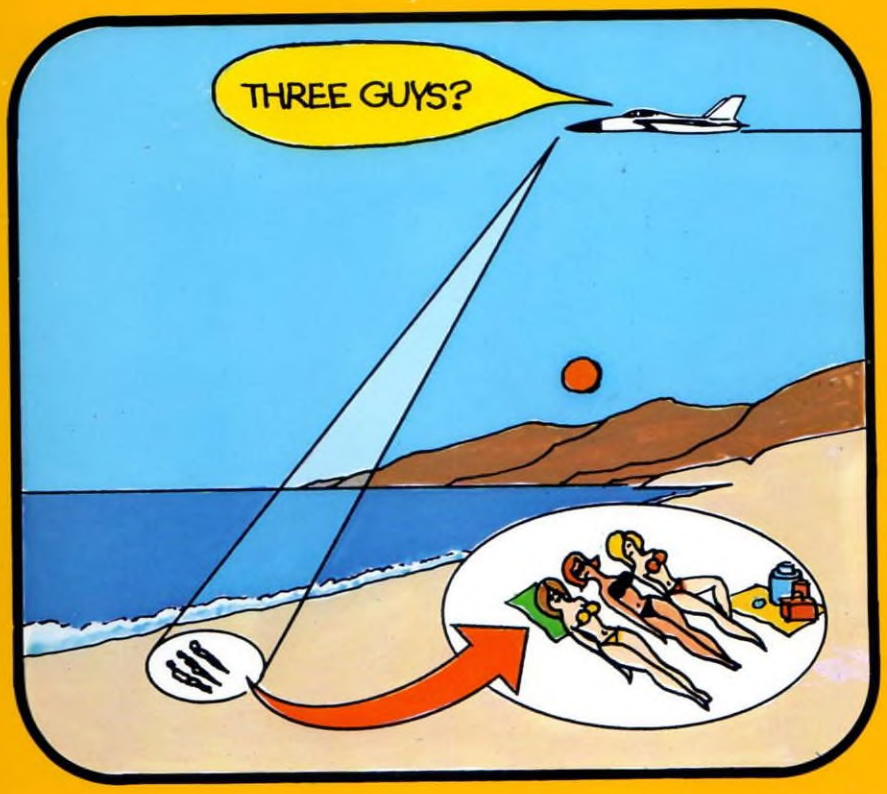
Multiple targets in close formation usually create a larger radar reflection; hence a larger radar energy return, and a longer detection range.



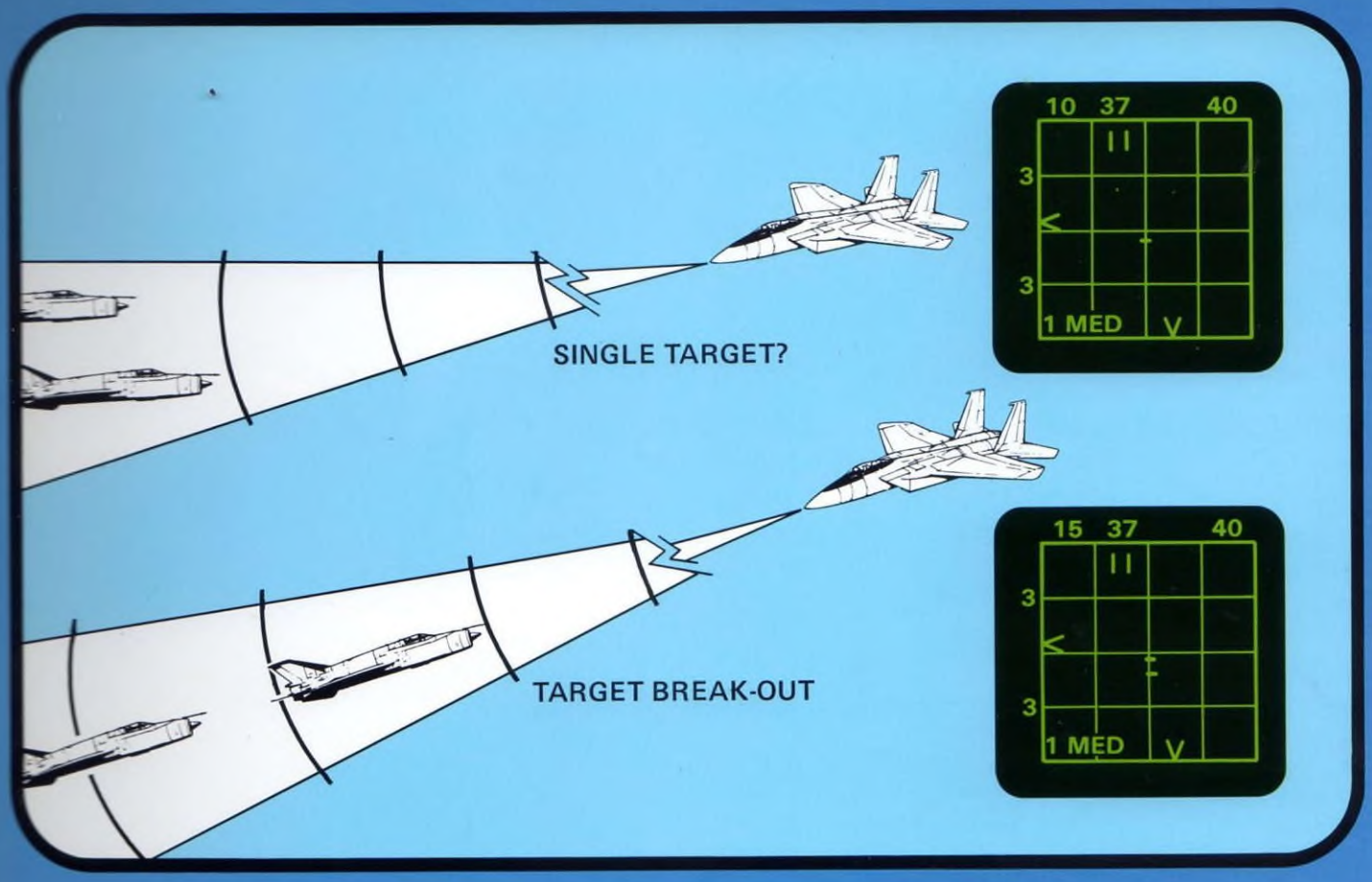
Detection range on second pass was only one-half of the detection range of first pass.

The High PRF mode utilized for look-up, head-on detection has greater detection range than Medium PRF required for look-down, tail-on targets. It is good to recall this, for at times during changing engagement conditions of a mission, the radar may seem to shorten its contact ranges. By reviewing the circumstances and environment in which we are operating we can many times avoid an unnecessary and misleading squawk.

The LRS mode utilizes both High PRF and Med PRF, the former optimized for forward aspect targets, the latter for tail aspect targets. The average transmitted power and sensitivity of the two modes differ considerably, thus longer range detections should be expected during HPRF operation against nose aspect targets. No detections against tail aspect targets should be expected during HPRF operation.



MULTIPLE DETECTIONS



Squawk

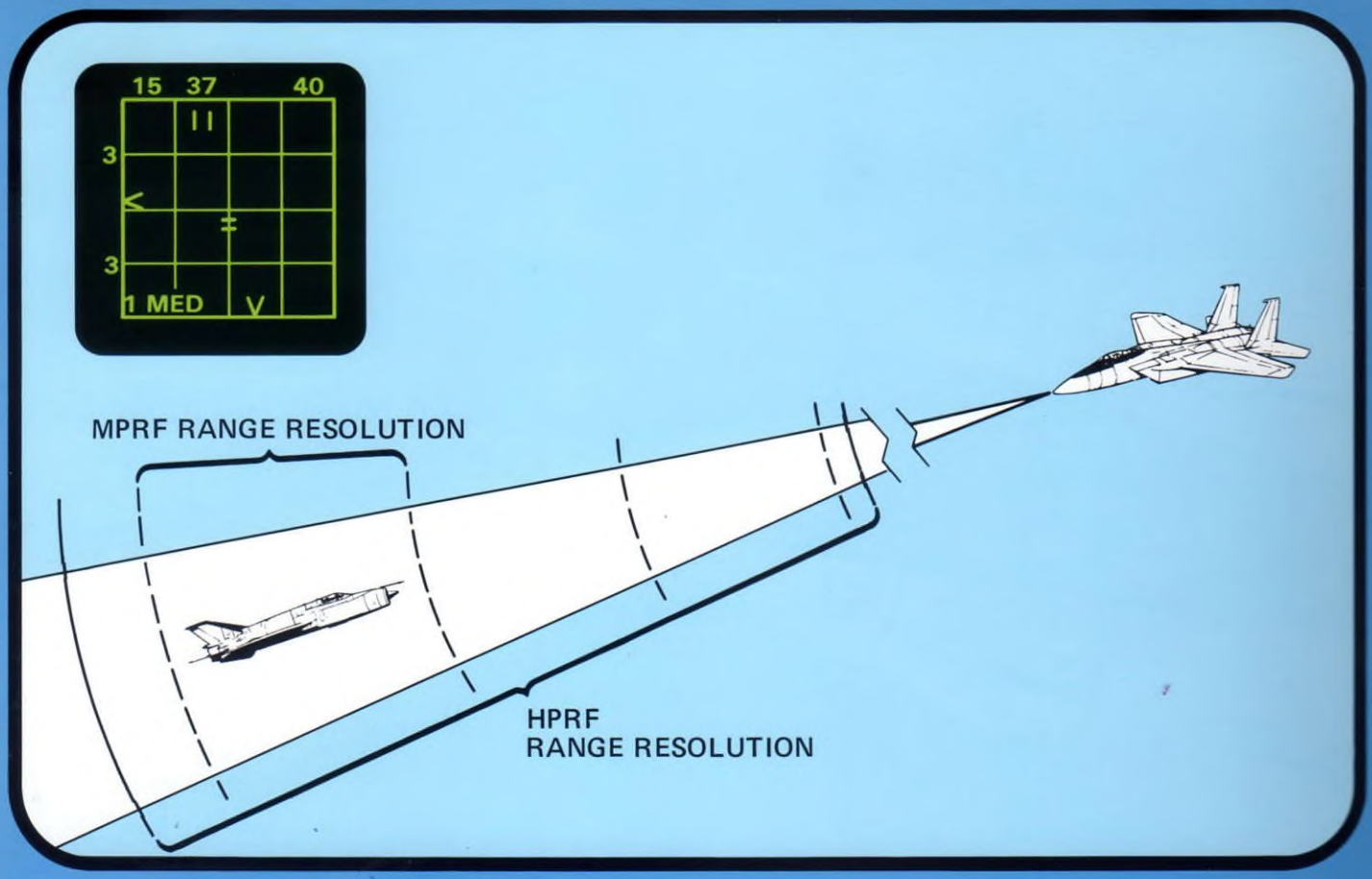
Can't determine the number of targets in the formation.

Pheno

Remember that the radar itself has limitations and the absence of the ability to discriminate multiple targets may be that the targets are closer together in range than the range resolution capability of the radar can handle. In such cases target breakout will not occur.

Design

Range resolution of the APG-63 is dependent on the mode in use and is optimized for each mode consistent with other parameters (prfs, pulse widths) and tradeoffs (detection range) which determine the radar performance requirements. Maximum target resolution is obtained on the MPRF bar in search mode.



Squawk

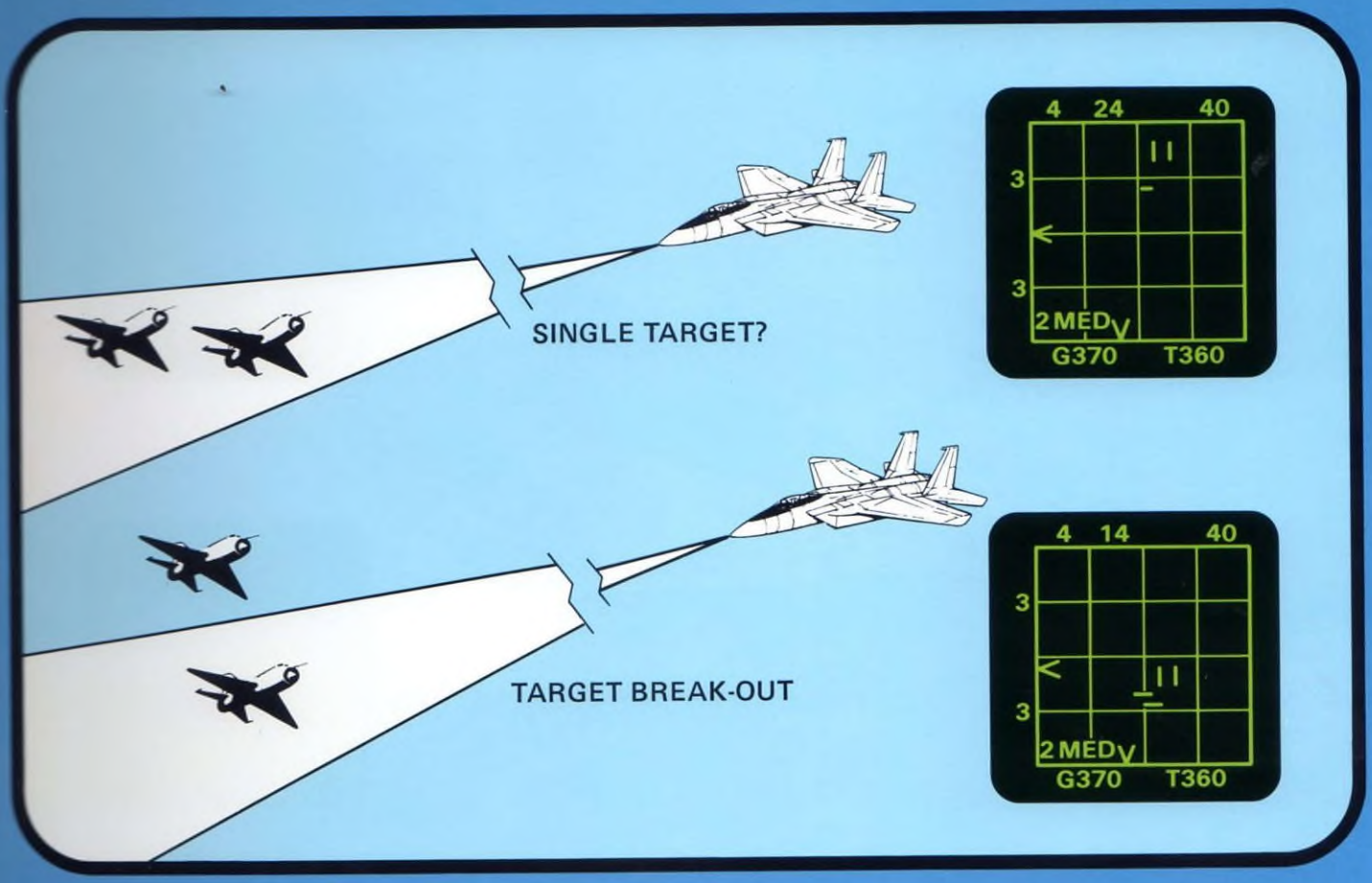
The target appeared at slightly different ranges on a bar-to-bar basis giving the appearance of a multiple target formation in the LRS mode.

Pheno

Due to the design characteristics of each mode (pulse width, PRFs, range resolving methods) and the LRS mode changes, resolution and accuracy differences of the modes may be apparent on the VSD by the bar-to-bar positioning of a target hit.

Design

Search range resolution and accuracy of the APG-63 is superior in the medium PRF mode. Once lock-on is established, very accurate ranging information is supplied from the radar set to the central computer in all modes.



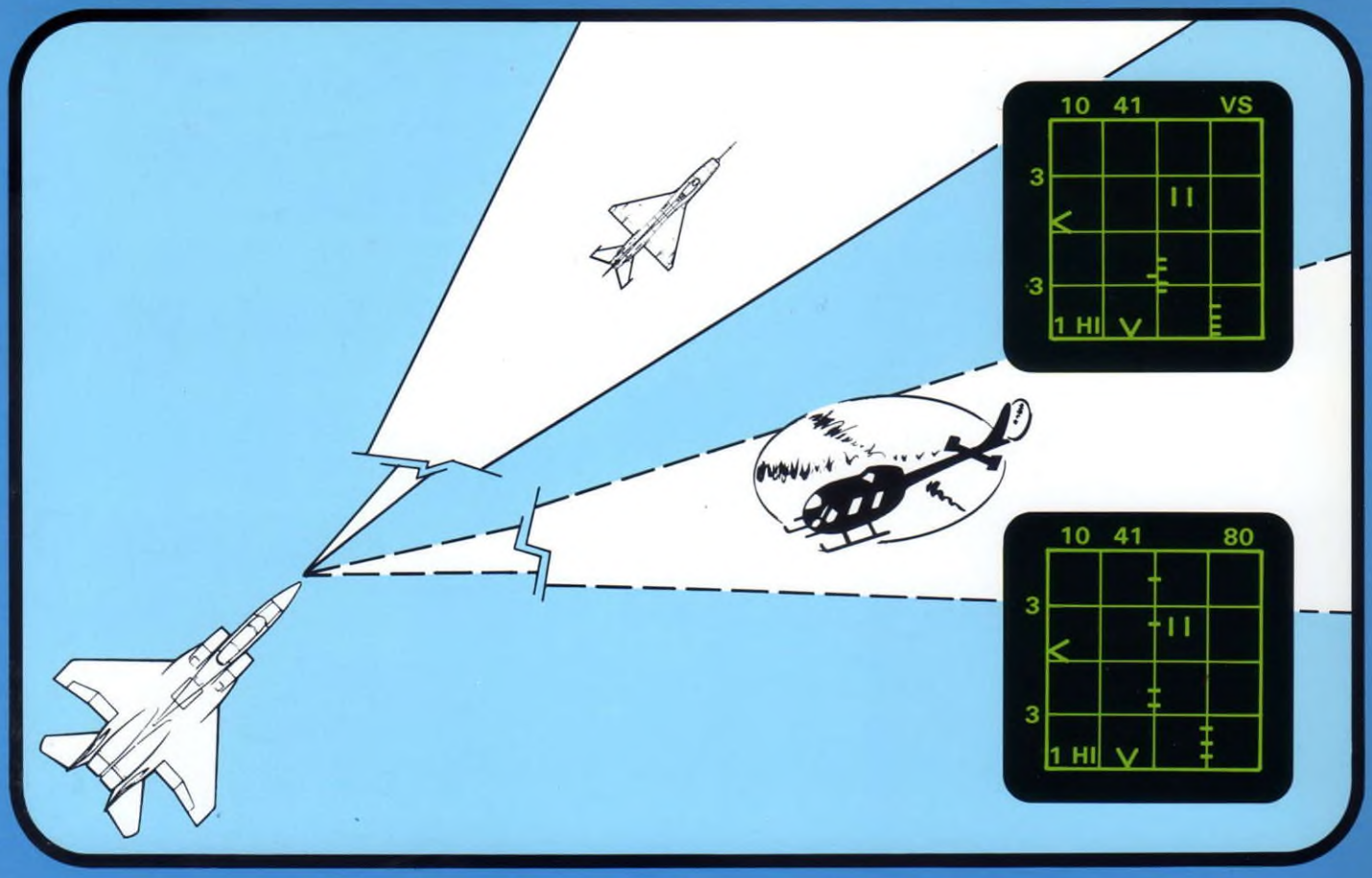
Squawk *I can't pick out the number of targets in the formation.*

Pheno

Often we forget the designed capabilities of a system. In the case of the APG-63 radar we find that multiple targets at long range and in close formation are covered in the same beam width and are seen as one target in most situations. As range closes, one of the targets may fall outside of the beam width which will then allow a determination to be made of the number of targets in the formation.

Design

Target resolution is primarily determined by the antenna beam width, which in turn is determined by the diameter of the APG-63 antenna. The diameter is restricted by the available volume within the radome.



Squawk

Got multiple velocity hits in VS from a single target. Target hits "splattered" in range in the LRS mode.

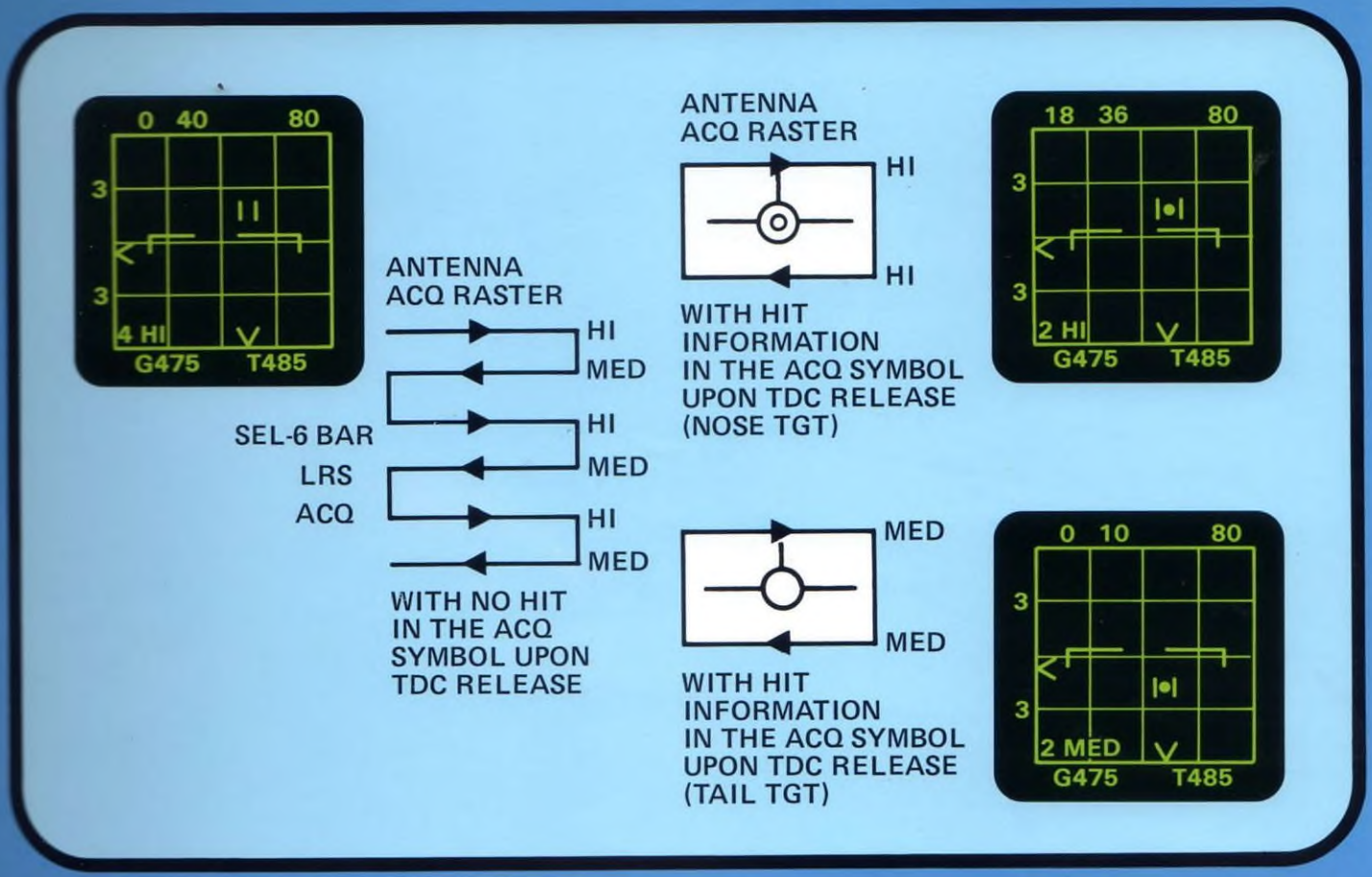
Pheno

In the VS (velocity search) or HPRF LRS (long range search) mode, jet engine modulation will create multiple velocity lines that may cause multiple hits at the same azimuth. Not only will engines cause this phenomenon but any rotating blades may create erroneous doppler spectrums. Such may be the case when you experience multiple detections in range and azimuth.

Design

Detections of secondary items in motion on a target (engine fan blades) is possible with a doppler radar such as the APG-63. This results in modulation of the primary doppler return and subsequent multiple erroneous velocity information.

LOCK-ON



Squawk

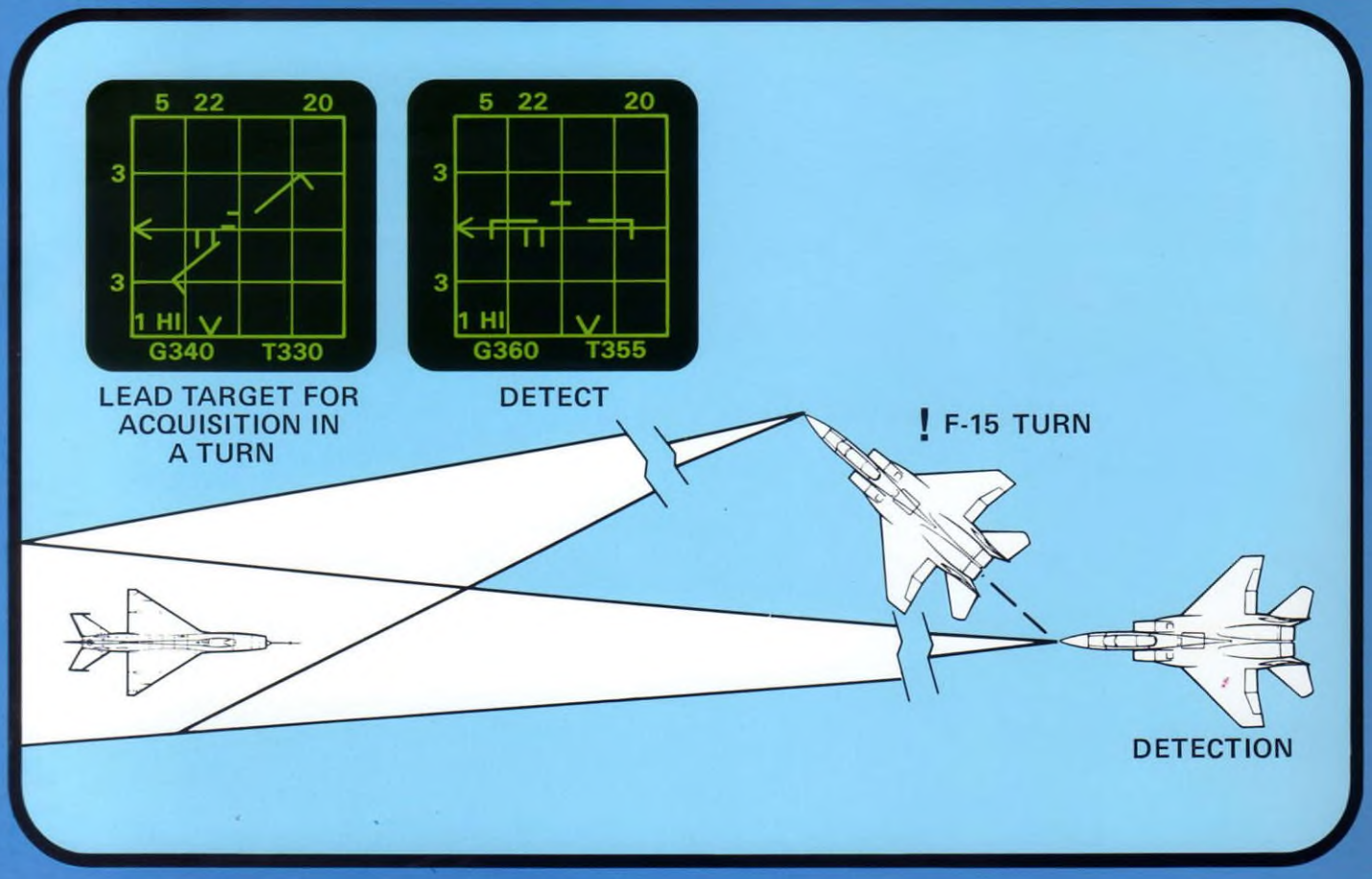
Experienced difficulty in obtaining a lock-on in LRS.

Pheno

The operator has a choice of selecting several frame storage times. By utilizing this capability lock-on can be enhanced. Keeping a hit on the scope helps the operator to position the ACQ symbol more accurately. Although the real target may have moved, the memory provides the necessary information for track initiation. With no new hit in the ACQ symbol, lock-on will not be accomplished.

Design

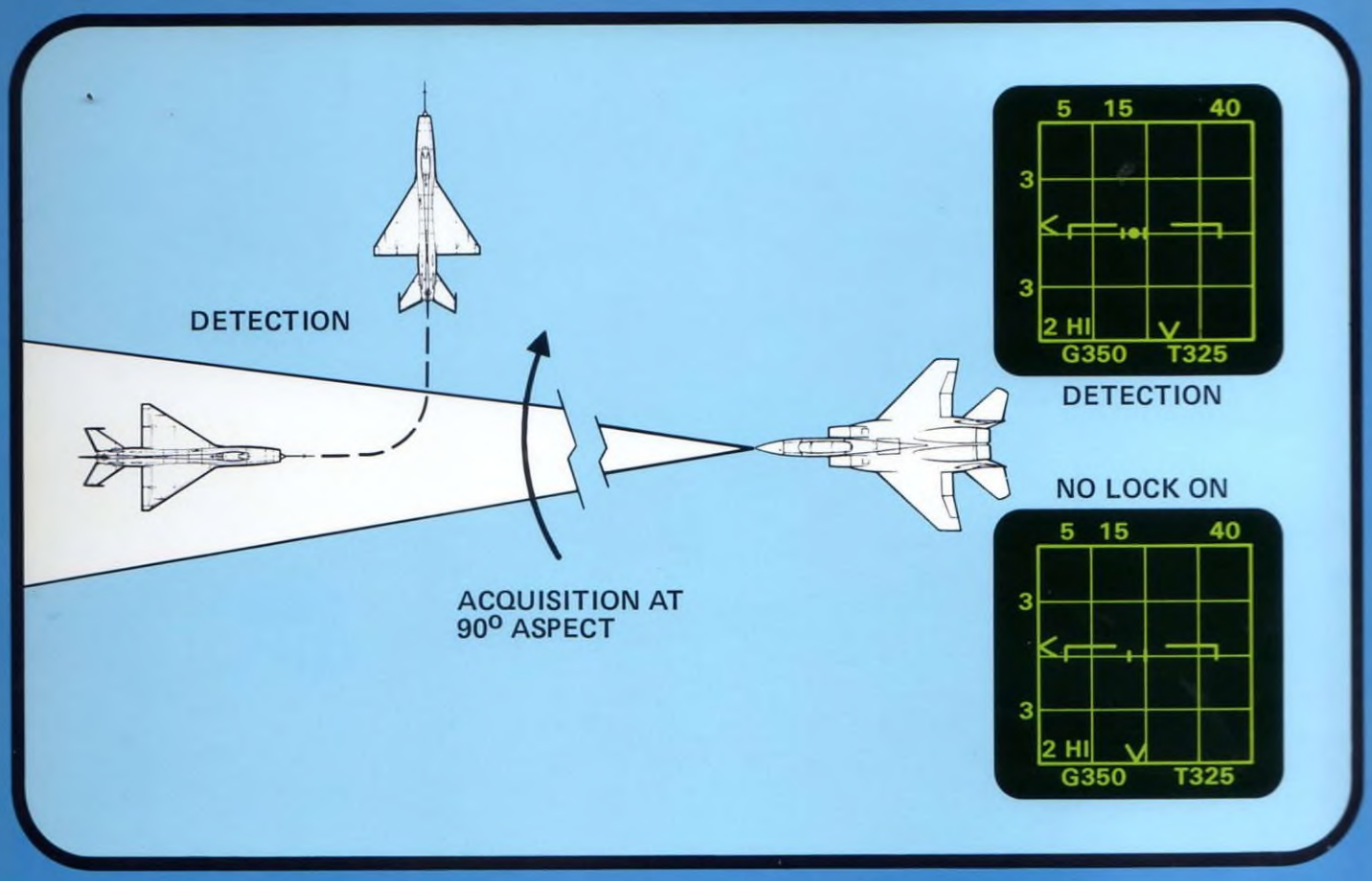
With the use of frame store, the antenna bar and prf for each displayed target is automatically stored in memory. When acquisition of a stored target is designated by the pilot's manipulation of the ACQ symbol and action switch, the radar automatically returns to the bar and prf on which the detection occurred, thus enhancing the probability of lock-on.



Will not lock on manually during maneuvers.

Manual acquisition during maneuvers with the F-15 can be troublesome. It must be remembered that the stored target position becomes erroneous as a turn is made and the target is not actually at the position detected. Some scope interpretation is necessary on the part of the operator and the ACQ symbols must lead the target in the maneuvering situation if manual lock-on is to be accomplished.

The target displayed on the VSD is not azimuth stabilized during the search mode. The azimuth position of a previously stored hit may be erroneous if either the target or F-15 maneuver between detection opportunities.



Squawk

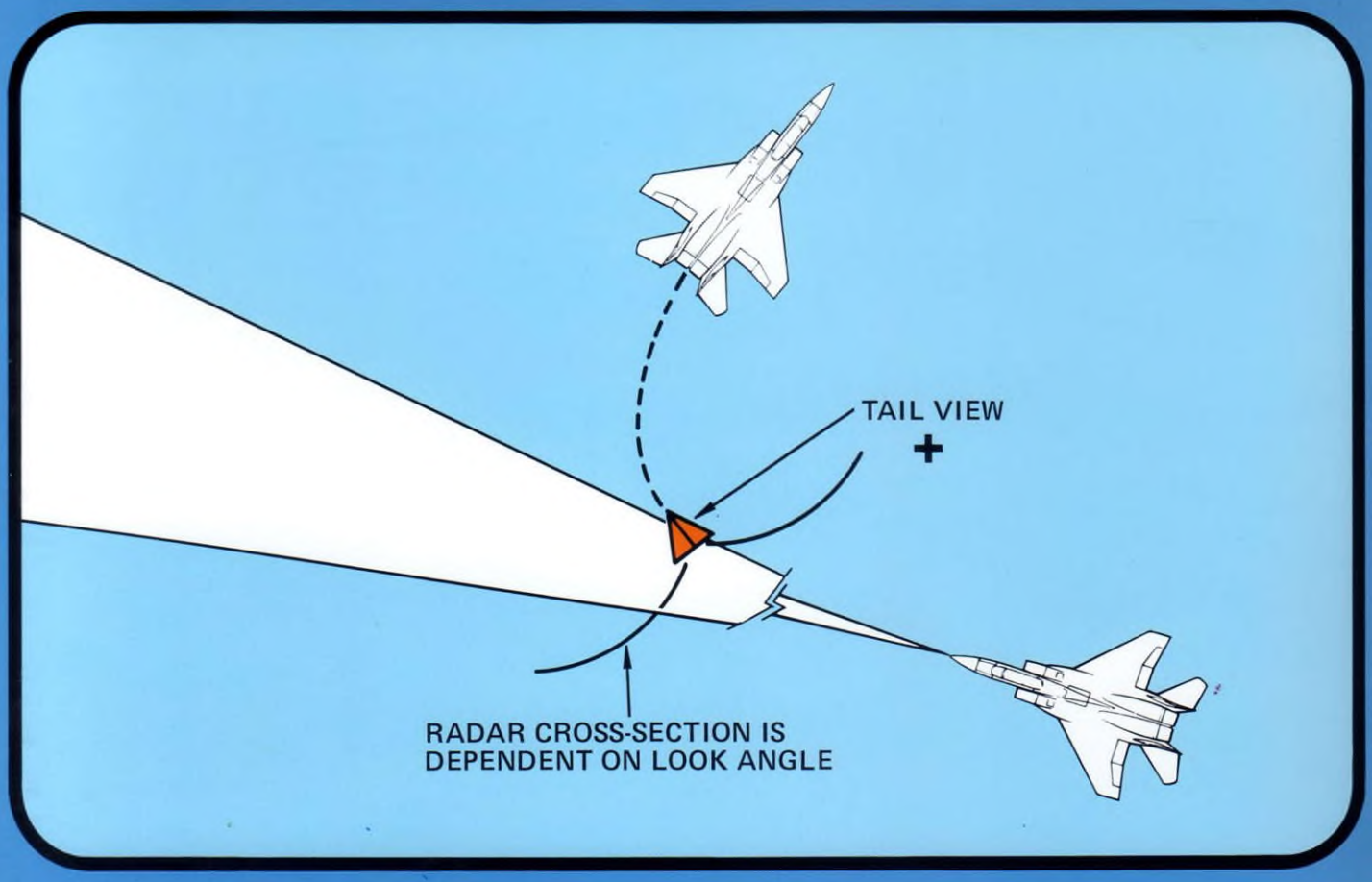
Will not lock on manually to a stored target hit.

Pheno

If the target is maneuvering after initial detection, the detection may not reoccur upon attempted acquisition. One reason may be that if the target maneuvers to beam aspect, the target doppler matches the clutter doppler and hence the target is not detectable. This situation can be momentary as he may pass through this doppler notch in short order.

Design

The use of frame store and multiple bar scan can create the possibility of interpreting hits on the VSD as current info, which may not be the case. The target may have maneuvered to a non-detectable position during several antenna frame times.



Squawk

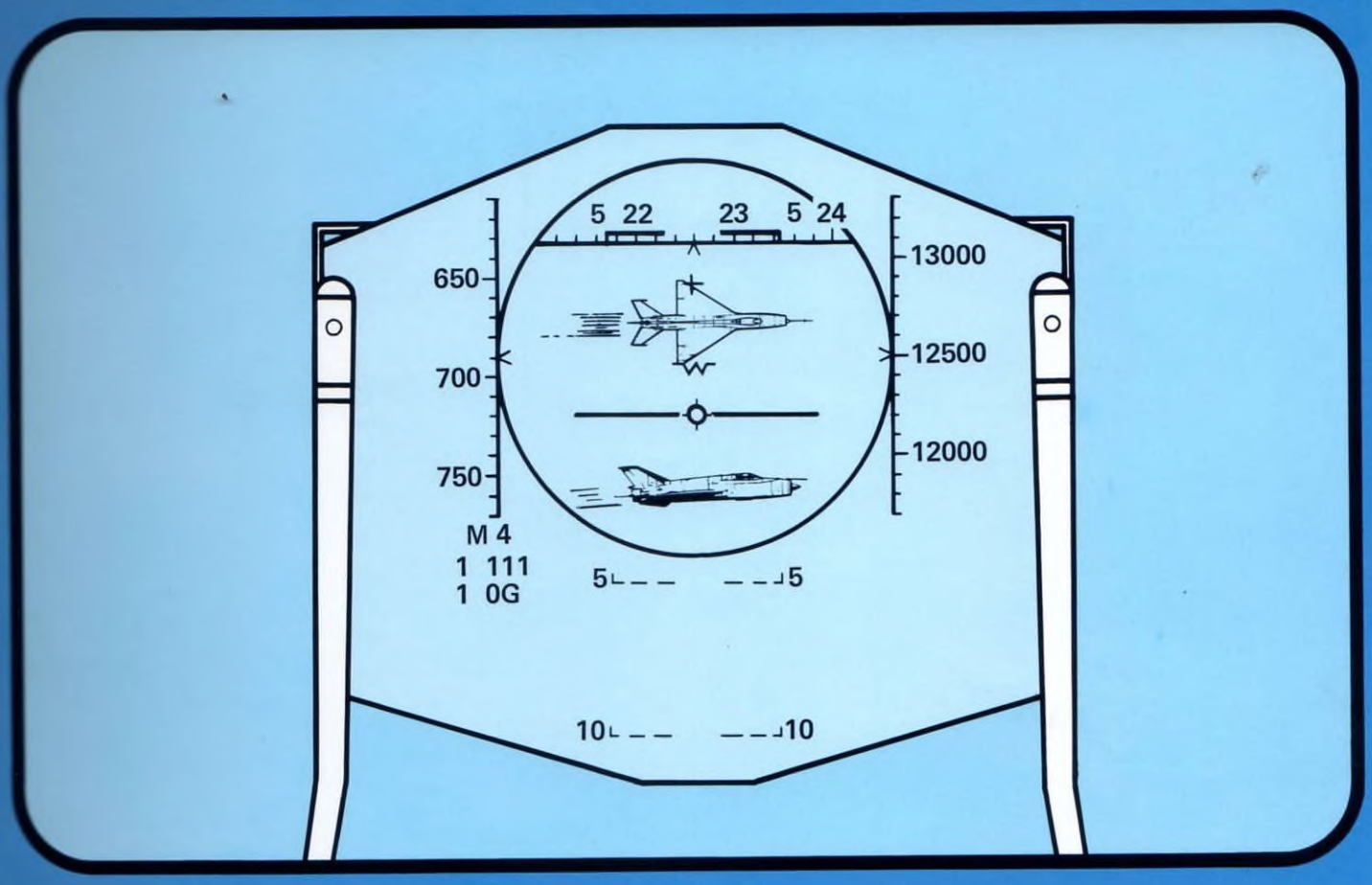
The radar will not lock on to a dart target.

Pheno

It is possible that some types of unaugmented dart targets will present a radar cross-section to the radar that is too small to detect. These are situations where the aspect angles cause the cross-section to reduce to near zero. If such a situation occurs, the unaugmented dart target flight pattern should be investigated because the radar may be functioning satisfactorily.

Design

Lock-on is not possible unless the target is at least detectable. Normally, detection sensitivity is slightly better than the acquisition sensitivity in the APG-63.



Squawk

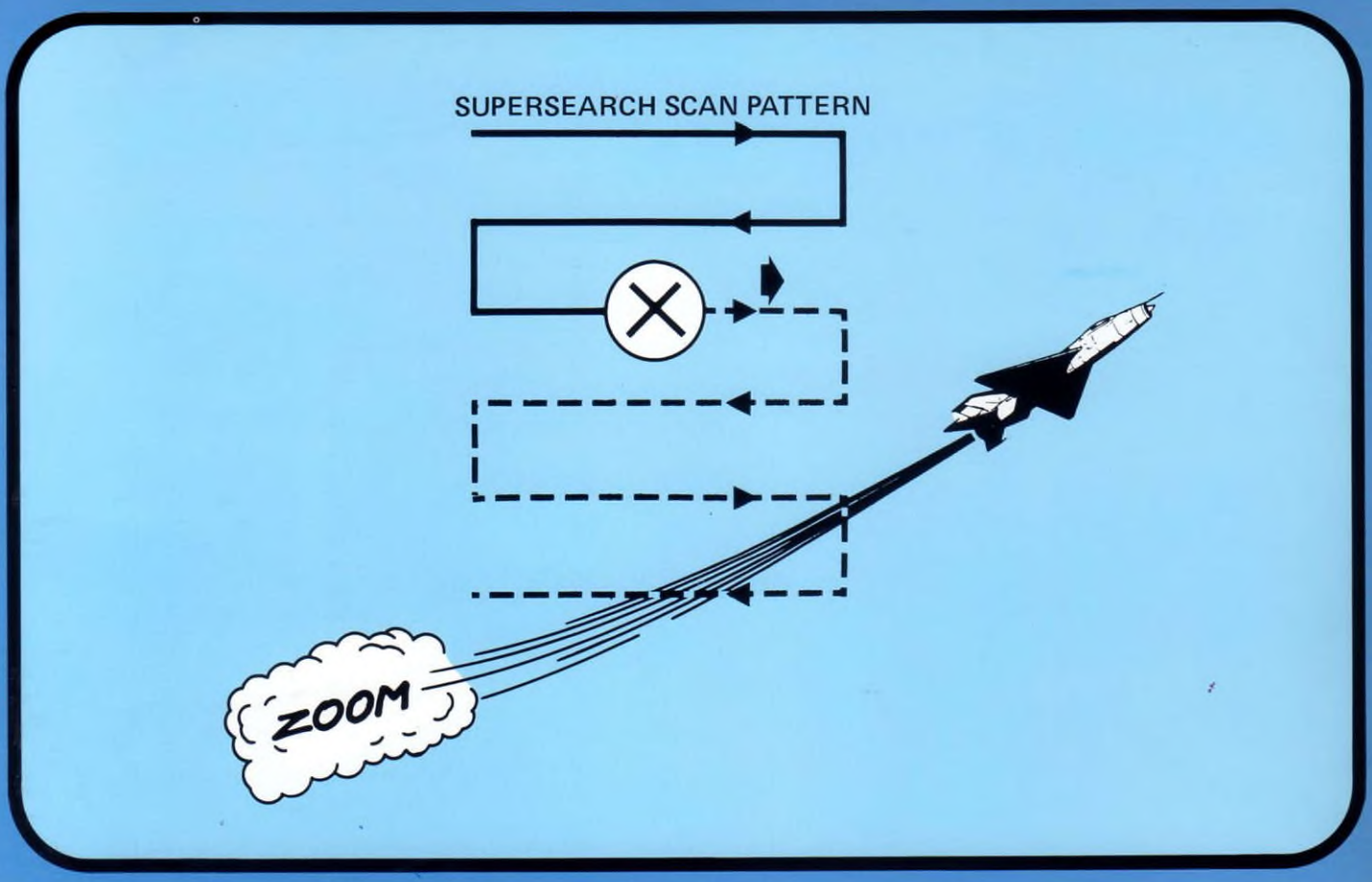
Boresight and supersearch are slow to lock on or fail to lock on to a target in the HUD (head-up-display) field of view.

Pheno

The APG-63 radar will not lock on to a target that has a 90° aspect angle with respect to the antenna line-of-sight because the doppler in this situation is the same as the ground clutter doppler. However, with only slight changes in these parameters, lock-on will occur.

Design

Boresight and supersearch are head-up modes. Targets must be in the HUD field of view for a brief period of time, within specific range limits, and must exhibit a doppler frequency different from that of clutter (different than 90° aspect angle) to achieve lock-on.



Squawk

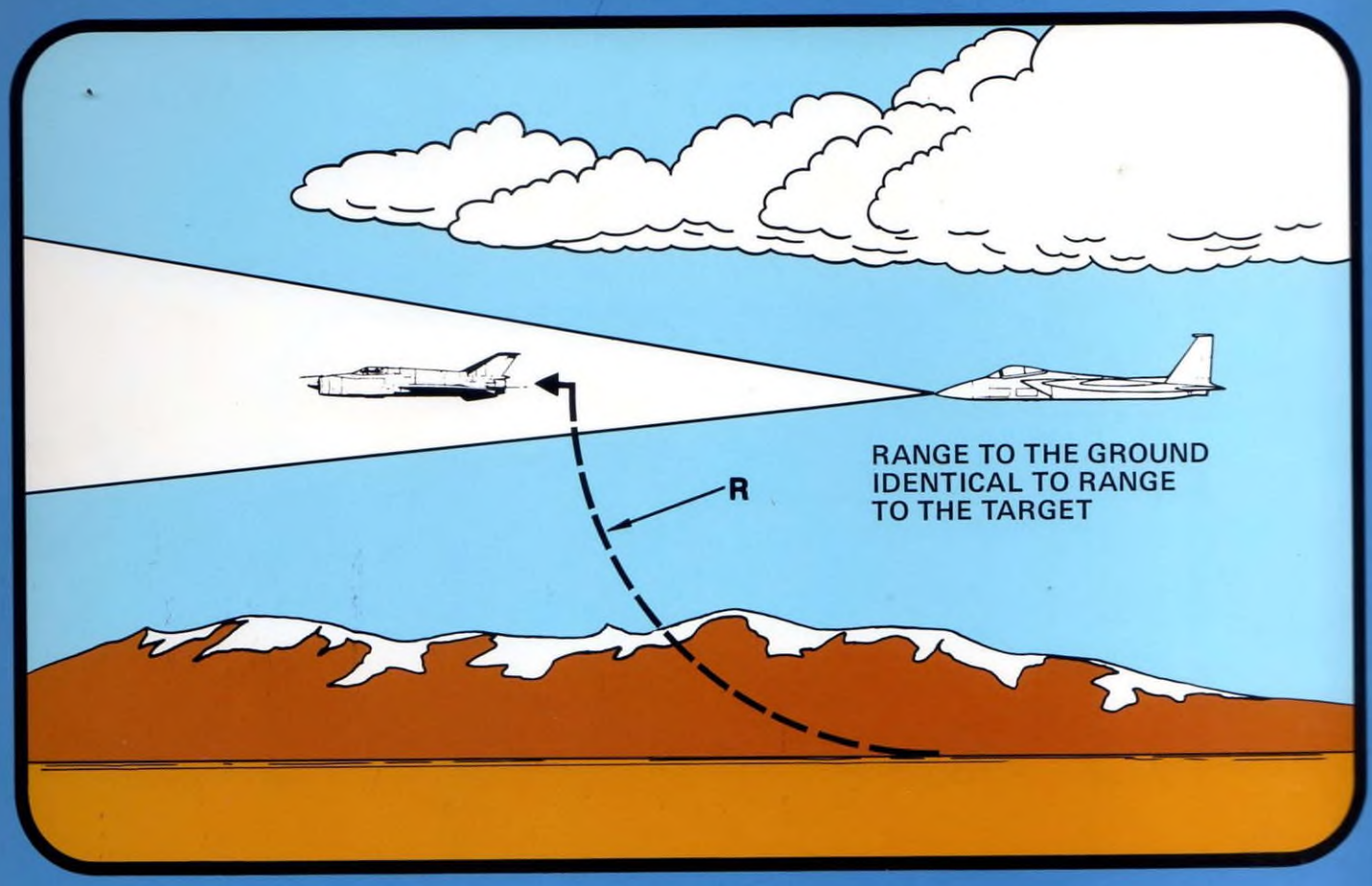
Will not lock on in supersearch.

Pheno

It is possible for a target to cross through the HUD field of view without being detected. In such a case the supersearch scan pattern simply has not had the opportunity to cover the entire search volume pattern. This may occur due to your own maneuvering across the target more often than the target maneuvering through your HUD field of view.

Design

During the supersearch mode, the radar antenna illuminates the entire volume of the HUD field of view within a limited time period. The pilot must maintain the target within the HUD radar field-of-view circle for at least this limited period in order to ensure the target is illuminated at least once by the APG-63 to achieve any probability of lock-on.



Squawk

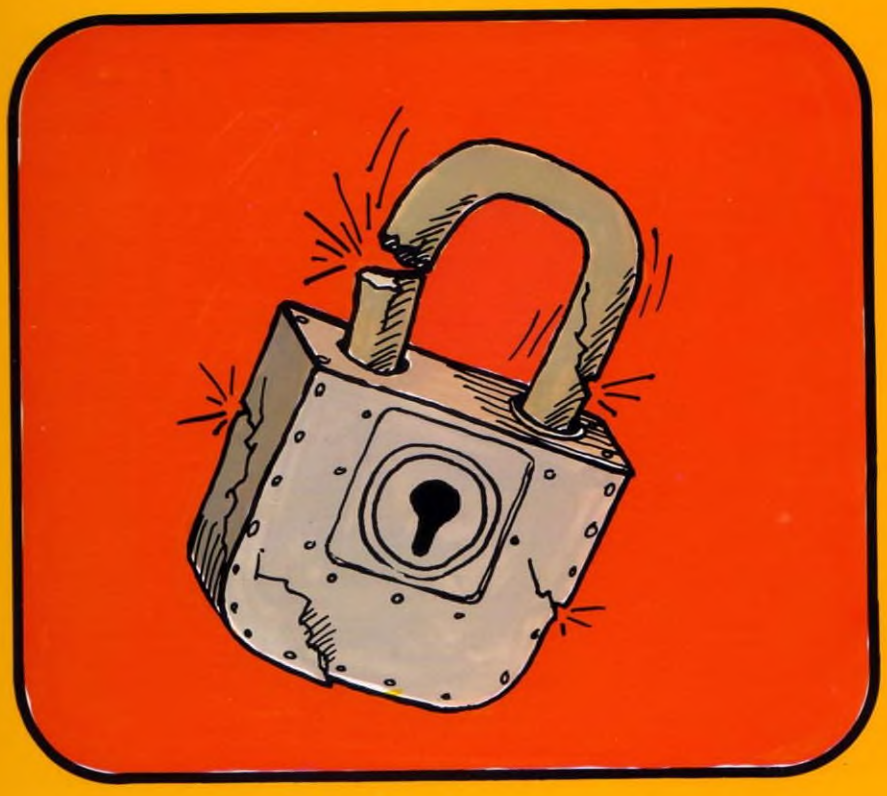
Lock-on is intermittent or breaks lock during supersearch or boresight.

Pheno

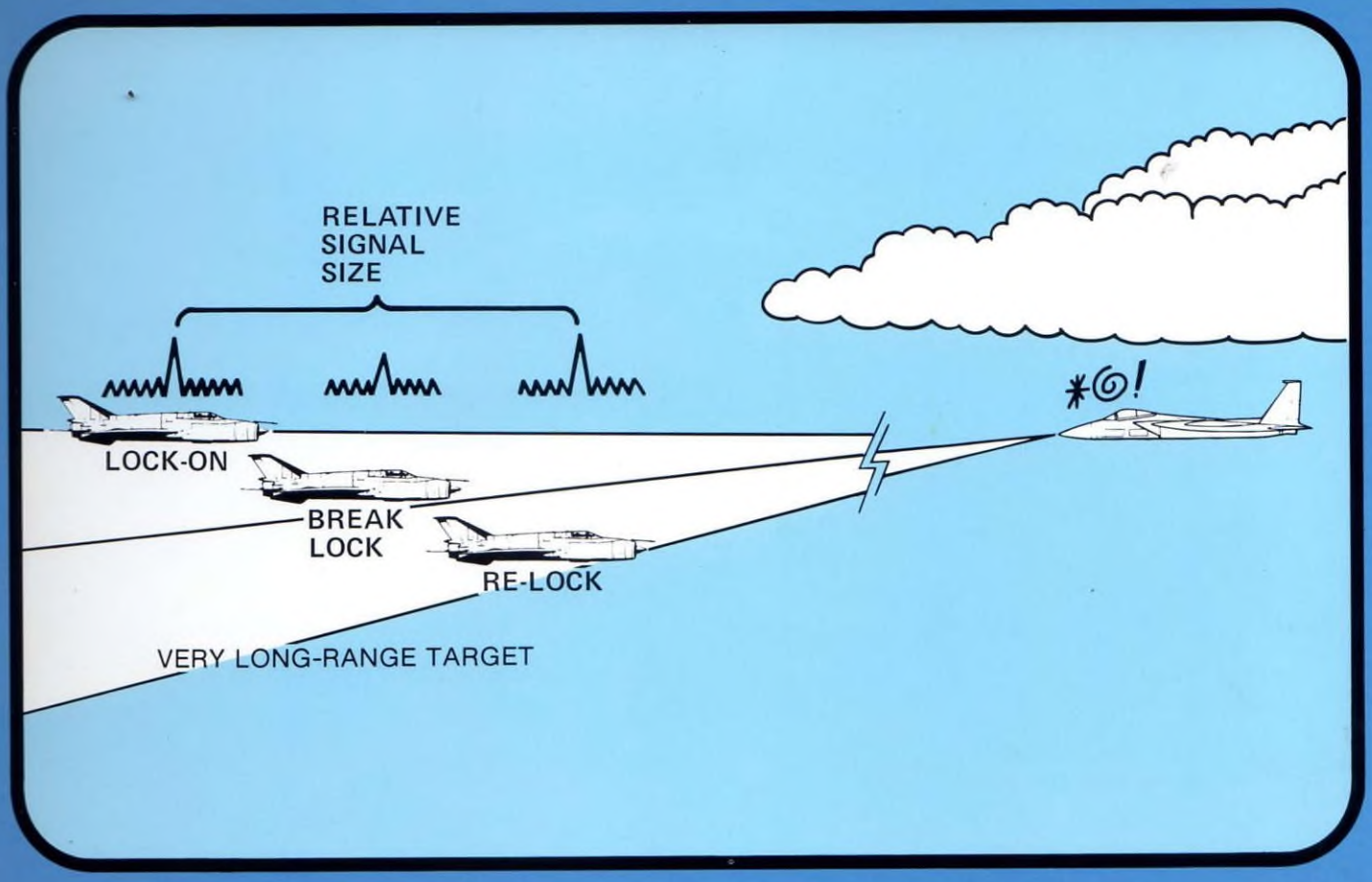
The radar may encounter difficulty with lock-on at low altitudes in the SS and BST modes if the target is small in size and its range is identical to the terrain clearance of the Eagle. In this situation there are times when the ground return is dominant, thus preventing target return recognition by the radar necessary for lock-on. Establishing a different range differential (assuming Vc was 0) will usually clear the difficulty.

Design

The APG-63 adjusts thresholds in accordance with the strength of the clutter return in a series of range bins. Target returns are hence desensitized in MPRF when they compete with clutter in the same or adjacent range bins.



BREAK LOCK



Squawk

The radar breaks lock at long ranges.

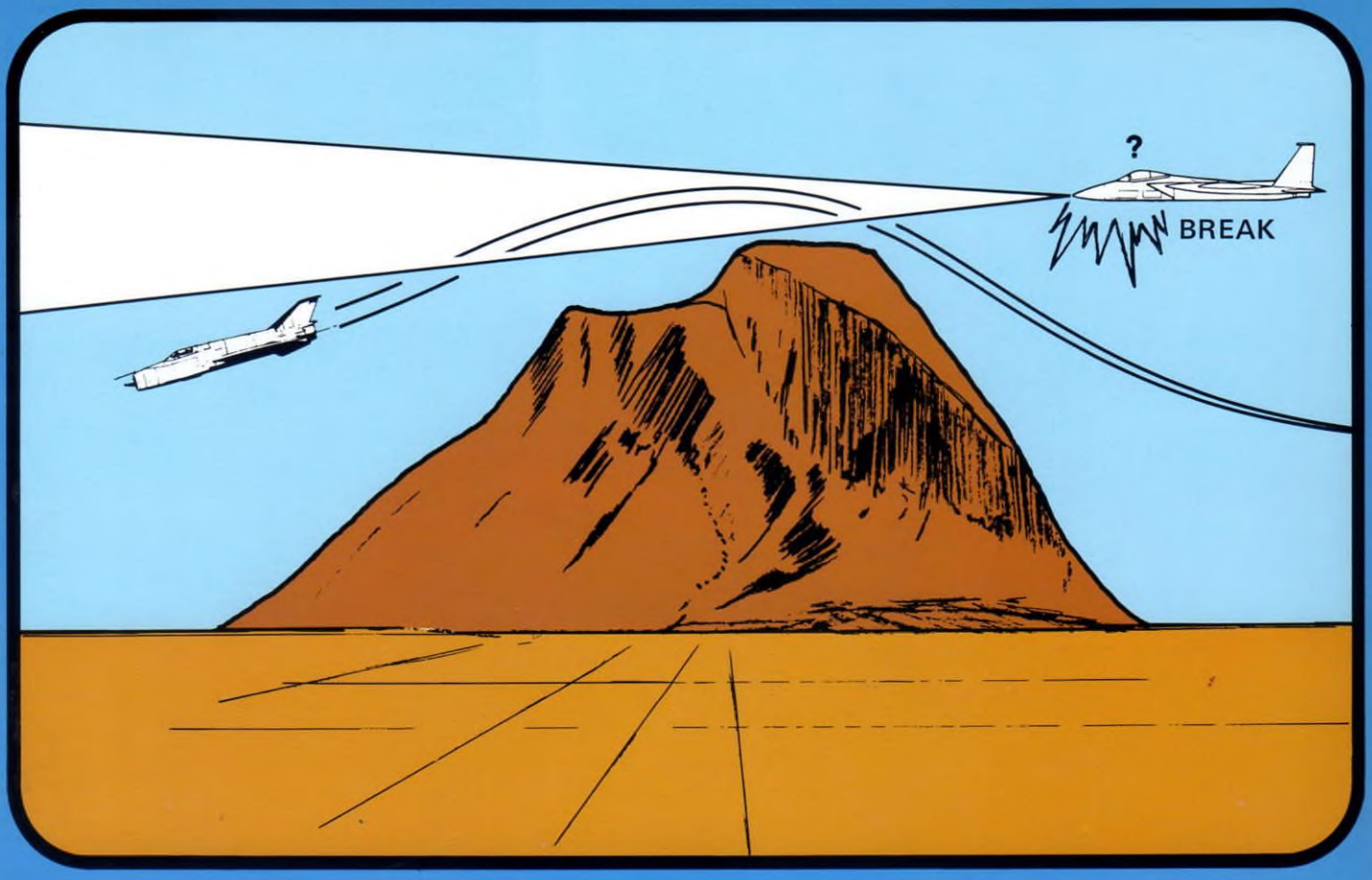
Pheno

It is true that we expect the radar to remain locked on to the target once acquisition is accomplished. However, on occasion it is normal for the system to break lock when one of several situations develops.

When locking on at maximum range, we may encounter target fades over a period of time long enough to cause break lock. A second lock-on may overcome this break lock situation and the engagement can be completed.

Design

Acquisition range sensitivity of the APG-63 is normally slightly less (~10%) than the maximum detection range. Break locks immediately after a long range lock-on can usually be considered normal.



Squawk

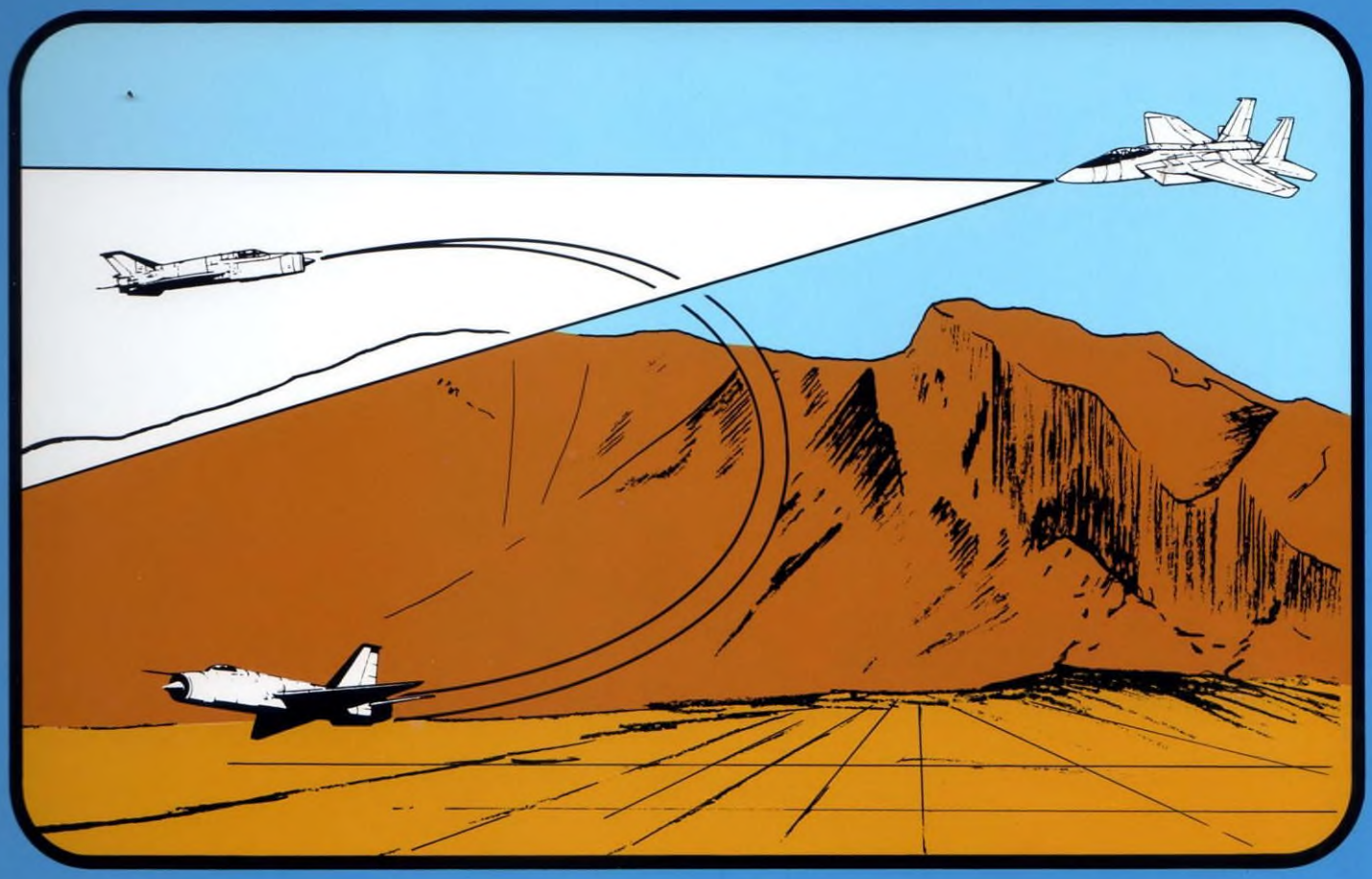
Broke lock-on for no apparent reason.

Pheno

Although this situation may be rare, it has happened before and undoubtedly will occur again sometime. After initial lock-on, the target may hide from the radar line of sight by dropping behind a mountain or large obstacle, thereby breaking target lock-on.

Design

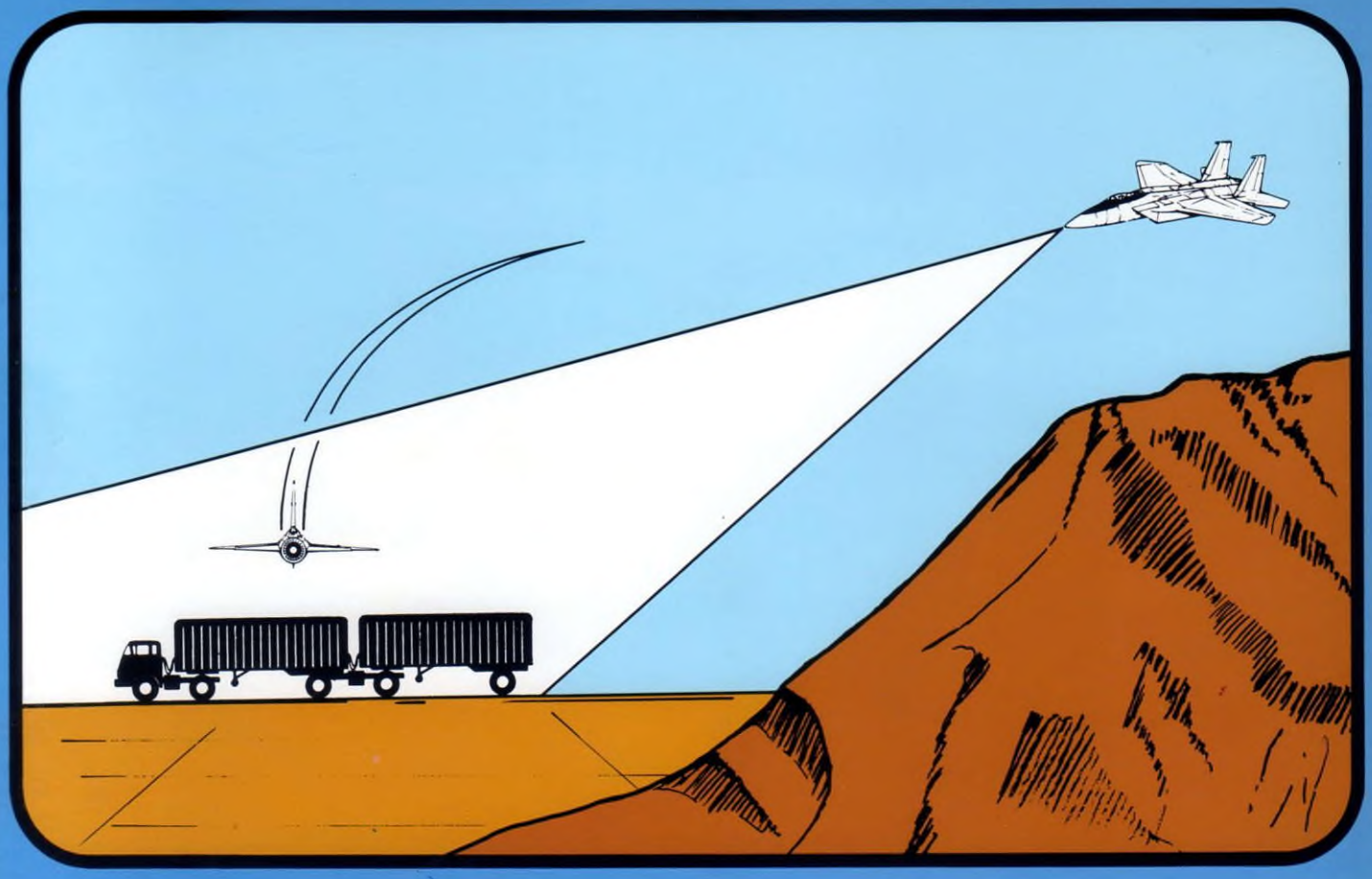
Illumination of the target is only one of several requirements for tracking of targets.



Breaks lock when target does 180° turn.

The radar itself has mode-dependent detection range capabilities and it is good to review these on occasion. A long range lock-on in HPRF on the nose may be accomplished; however, if the target performs a 180° turn we could lose lock-on as the target now is beyond the MPRF range capability on the tail. The radar sensitivity is much greater on the nose than on the tail due to the superior detection capabilities of the HPRF mode.

A change in aspect angle may force the APG-63 to change tracking mode. Similar range performance differences between HPRF and MPRF exist during track as during search. This is an important factor to remember. A 180° change in aspect during look-down track also requires the radar to track through the main beam clutter return (during the 90° beam aspect portion of the turn). A nose to tail aspect change with continuous track at medium ranges is normally always successful in MPRF, whereas the range is slightly less in HPRF.



Squawk

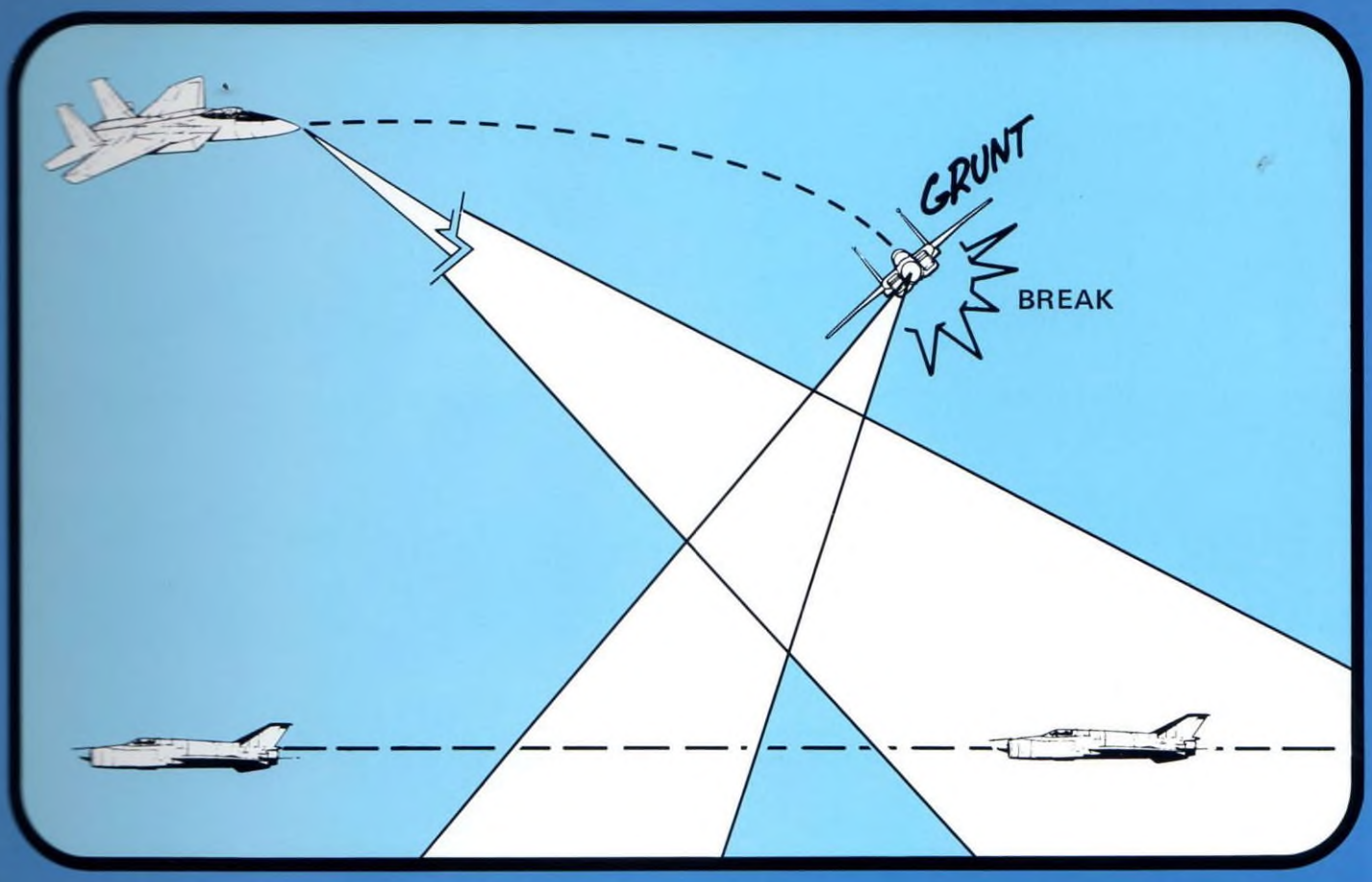
Transfer lock-on to ground, or to ground moving target, or to second target.

Pheno

On occasion, a second target may enter the radar tracking gates, creating problems for the radar tracker, and may cause a break lock or a track transfer. Remember that target radial velocities must be nearly the same for this to occur.

Design

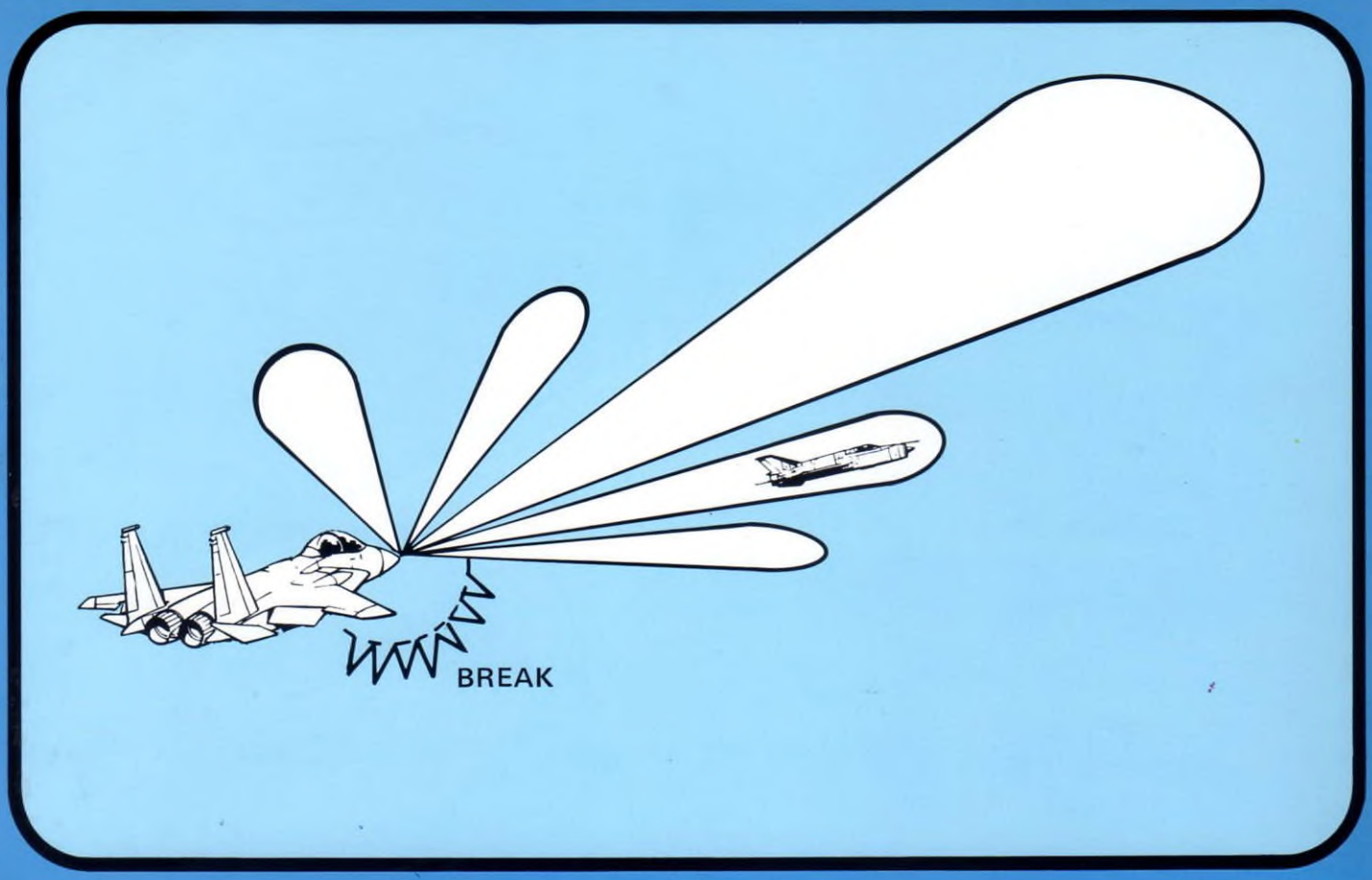
The radar is subject to transfer lock-on to the larger of two targets when the doppler and range parameters of the two are nearly identical.



Squawk *Breaks lock or loses lock during high turning rates.*

Pheno In a dynamic situation, flight attitudes and tactical situations are changing constantly. During this peak work load period by the pilot, it is disheartening to say the least to have the radar break lock. In this environment, the radar antenna may momentarily hit the gimbal limit and the break lock may occur. This can happen during many flight conditions and often occurs on a nose-tail conversion.

Design Radar antenna gimbal limits are ± 60° relative to the fuselage reference line (FRL) of the aircraft. The MRM and SRS ASE circles flash on the HUD and VSD when the radar cone angle is equal to or exceeds 50° as a warning that the antenna gimbal limits are approaching.



Squawk

TD Box drifts off target after lock-on—Break lock occurs.

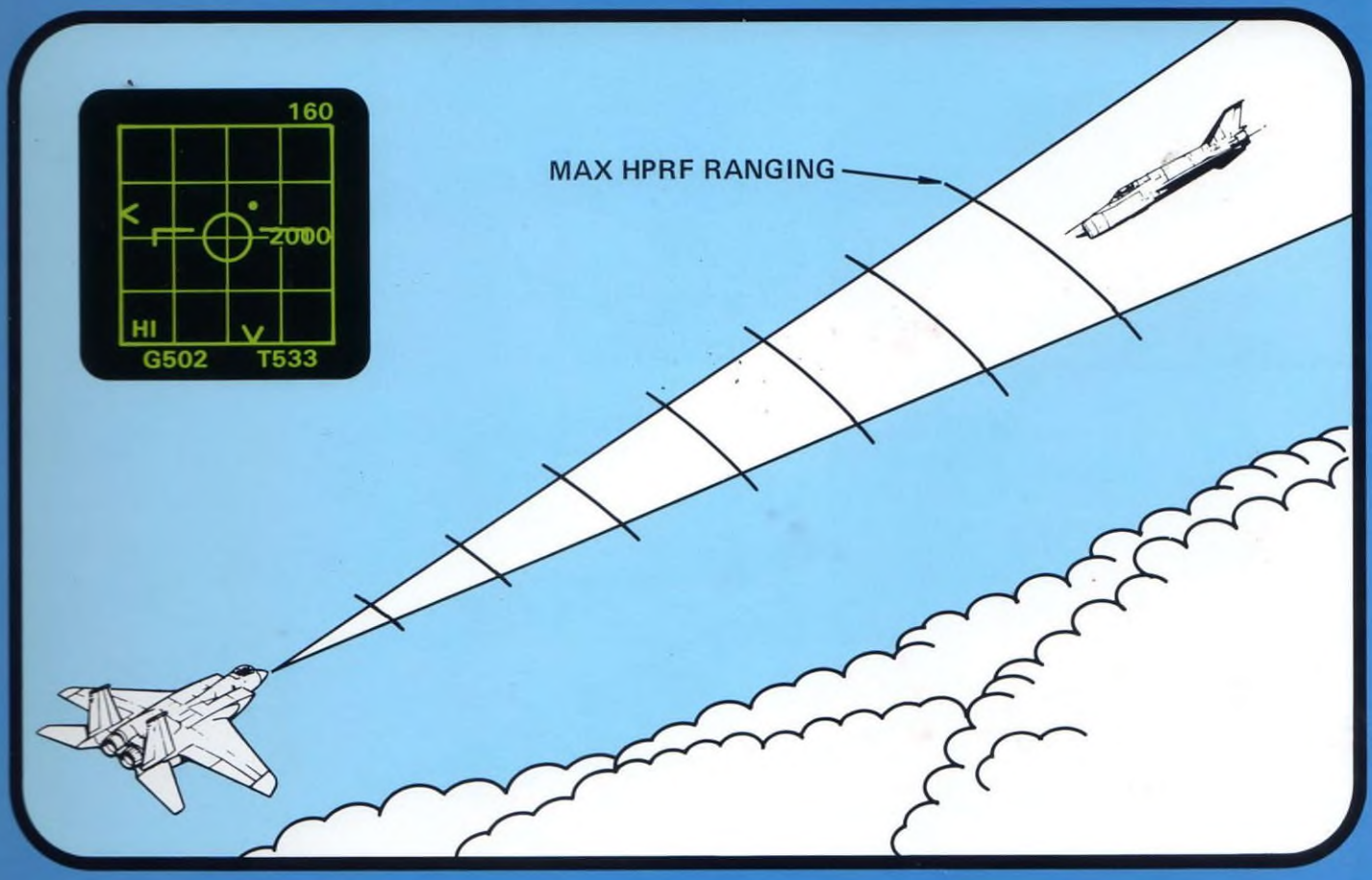
Pheno

During BST (boresight) or SS (supersearch) lock-on at extremely short ranges or on very large targets at medium short ranges, the radar may enter track on the target returns generated from an antenna side lobe. Under these conditions, improper antenna positioning errors are generated and break locks will occur. Lock-on will have to be reinitiated to obtain main lobe tracking.

Design

The APG-63 antenna has extremely low level side lobes; however, finite levels are present, creating side lobe energy from nearby illuminated targets/clutter.

MISCELLANEOUS



Squawk

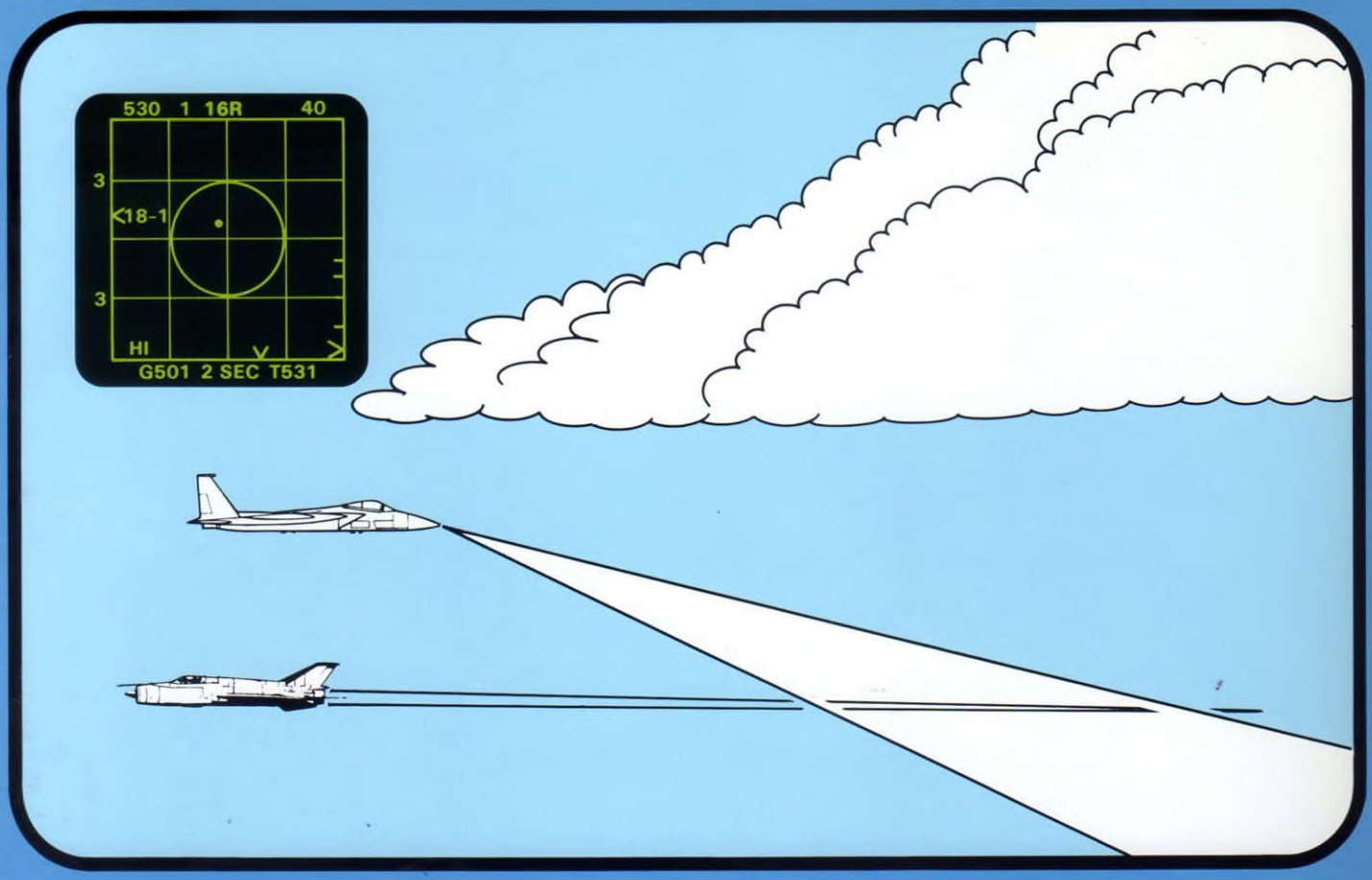
I had a VS (velocity search) lock but the radar wouldn't range until considerable delay.

Pheno

VS track may be established at a range which may be far in excess of the radar ranging capability. The target, if small, could also be within the radar ranging capability; however, full range track may still not be available since the signal strength required for detection is less than for ranging. Continued pursuit of the target will close the gap and range information will then be presented on the scope.

Design

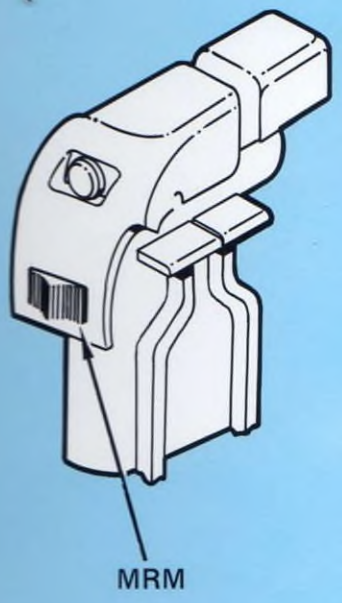
The APG-63 is mechanized to provide the specified maximum ranging limits. These limits are less than the maximum selectable display range limits. Large targets may be initially detected and acquired beyond the ranging limits. Small targets, acquired within the ranging limits, may not present range information due to the limited signal strength.

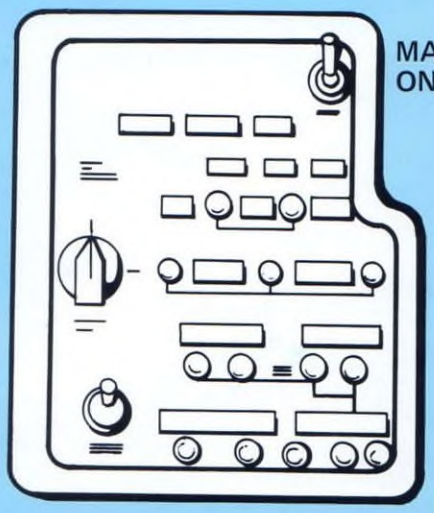


Target passed over/under me, but the radar remained in track.

Remember, if an AIM-7F launch is in progress, the radar is prohibited from returning to search (even at gimbal limits). The antenna may begin to wander after the loss of target until 1.3 times the displayed time-of-flight +15 secs expires. Steering information in this situation is highly erroneous and MEM may be displayed at the top of the VSD (vertical situation display).

The APG-63 is mechanized to continue in the HPRF track mode while the AIM-7F missile is in flight regardless of the track status until a command is received from the central computer indicating the computed time of flight has expired. The displayed time of flight assumes constant geometry (non-maneuvering target) following launch.





TARGET LESS
THAN 1.2 R_{MAX}

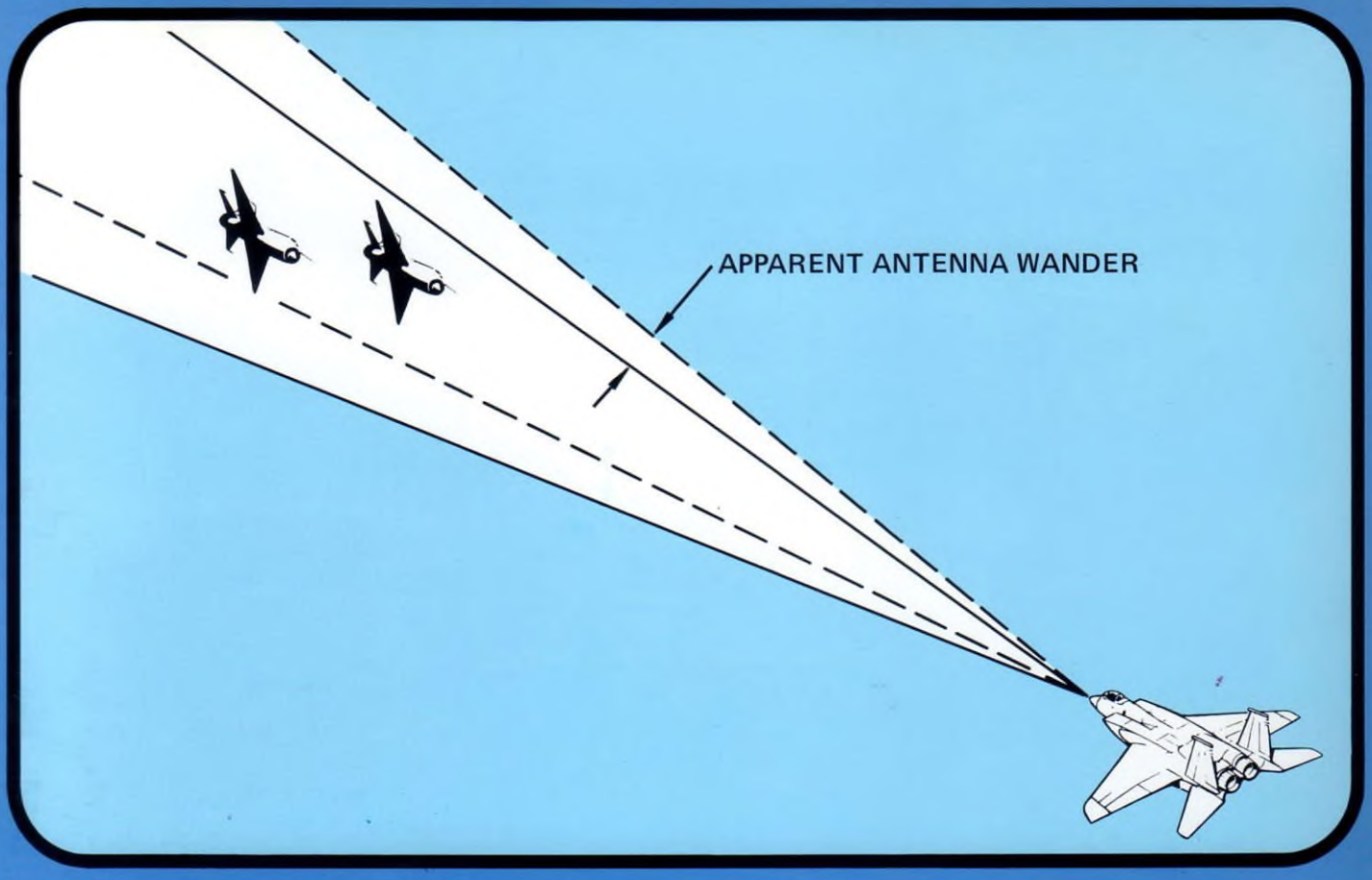
Squawk *Radar goes to Flood on Launch Command.*

Pheno

When MRM (medium range missile) and Master Arm is selected and the range is less than 1.2 Rmax, the radar must be tracking in the HPRF mode for MRM compatibility. If the radar is tracking in the MPRF mode, a track transfer to HPRF will be attempted automatically. If this transfer is unsuccessful, the radar is programmed to select a flood mode launch when the launch command is received. Often a lock-on is obtained in SS or BST (MPRF tracking) with the above armament conditions selected. If the pilot immediately initiates missile launch prior to the HPRF track transfer, a normal flood launch results.

Design

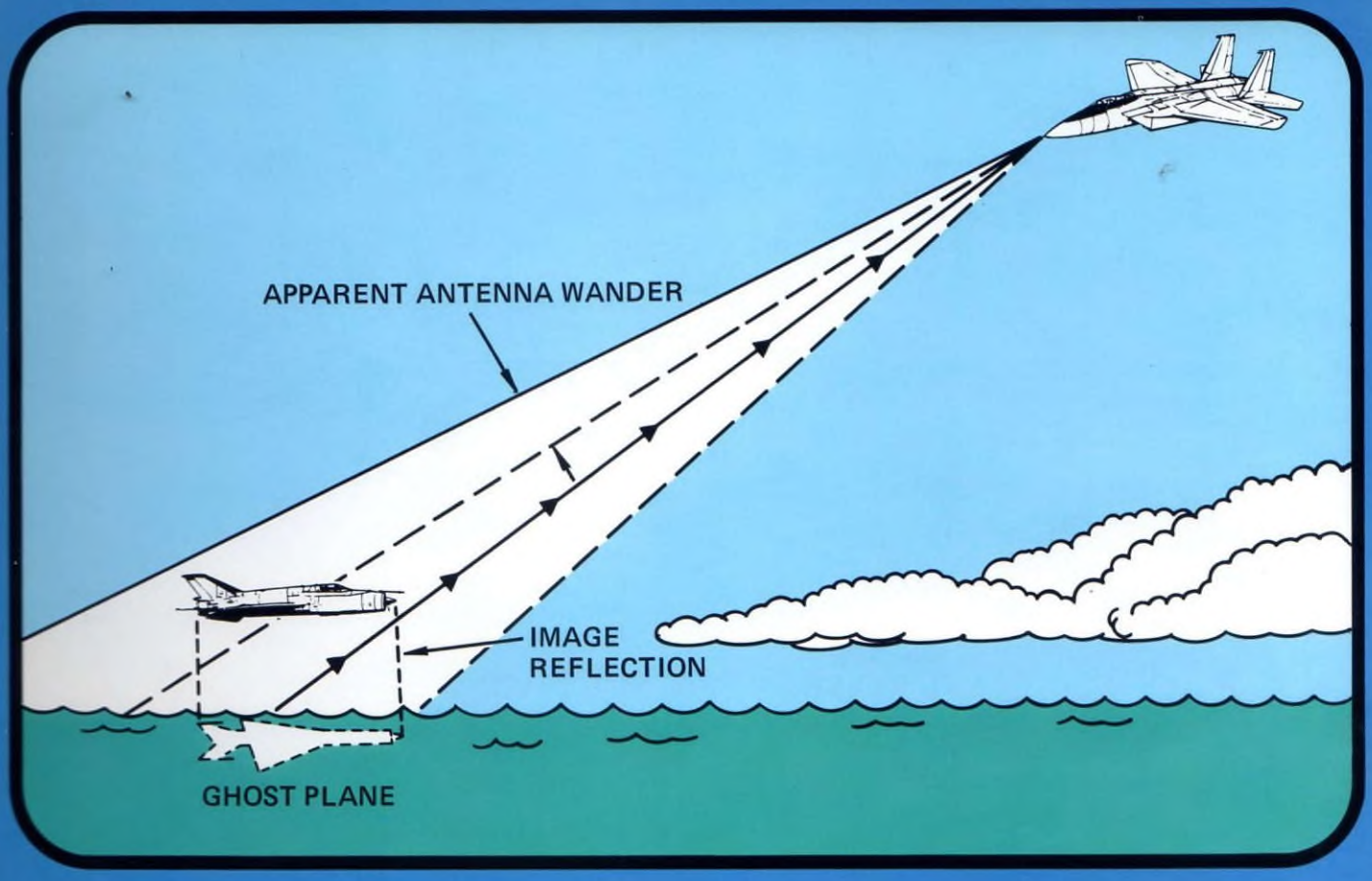
The APG-63 is mechanized to provide illumination compatible with the AIM-7F missile during and subsequent to launch conditions even though radar track is impossible due to the tactical situation. This is accomplished through the use of the flood antenna. When lock-on is accomplished via either BS or SS mode with MRM and Master Arm selected, a wait of approximately 3 seconds prior to launch may allow a successful transfer. The HI cue on the VSD confirms transfer.



The target parameters were unstable and the steering dot wandered back and forth.

This phenomenon may present itself when two targets are in the antenna beam and periodically the antenna centers on one and then the other. It is good practice to suspect that two targets may be present if the steering dot is oscillating.

When targets in the antenna beam width are nearly equivalent in size, range and doppler and are being tracked, the APG-63 may transfer track between the two.



Squawk

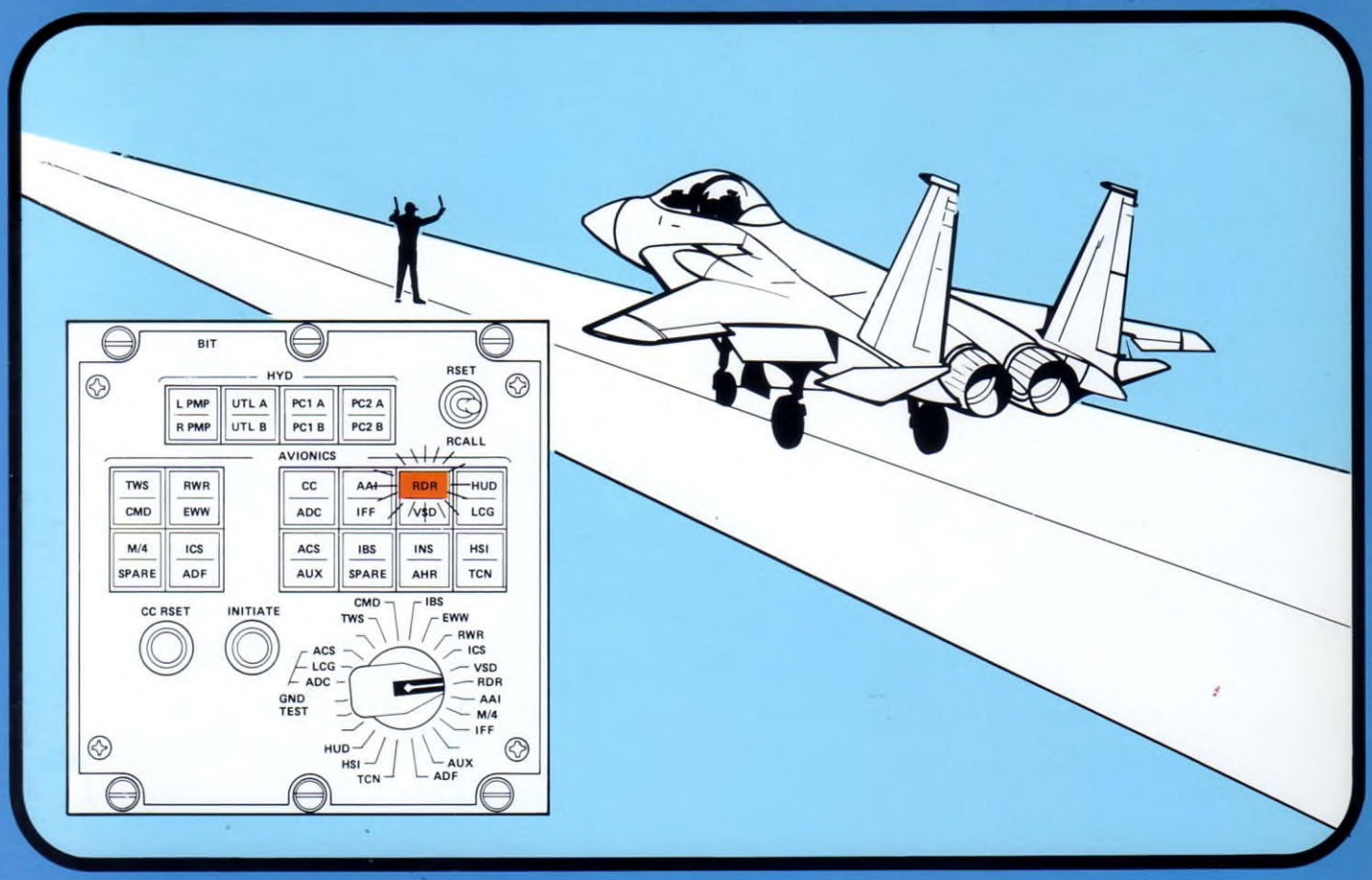
Tracking is erratic and unstable during look-down conditions.

Pheno

The cyclic condition of the steering dot wandering can occur in elevation over a very specific range when looking down over water or flat terrain. In this case, however, an image (ghost) exists momentarily.

Design

Image tracking is a phenomenon related to look-down radars and the APG-63 may at times exhibit this phenomenon.



Squawk

The radar broke; had a radar BIT light airborne. Ran BIT (built-in-test) on the ground and it is clean.

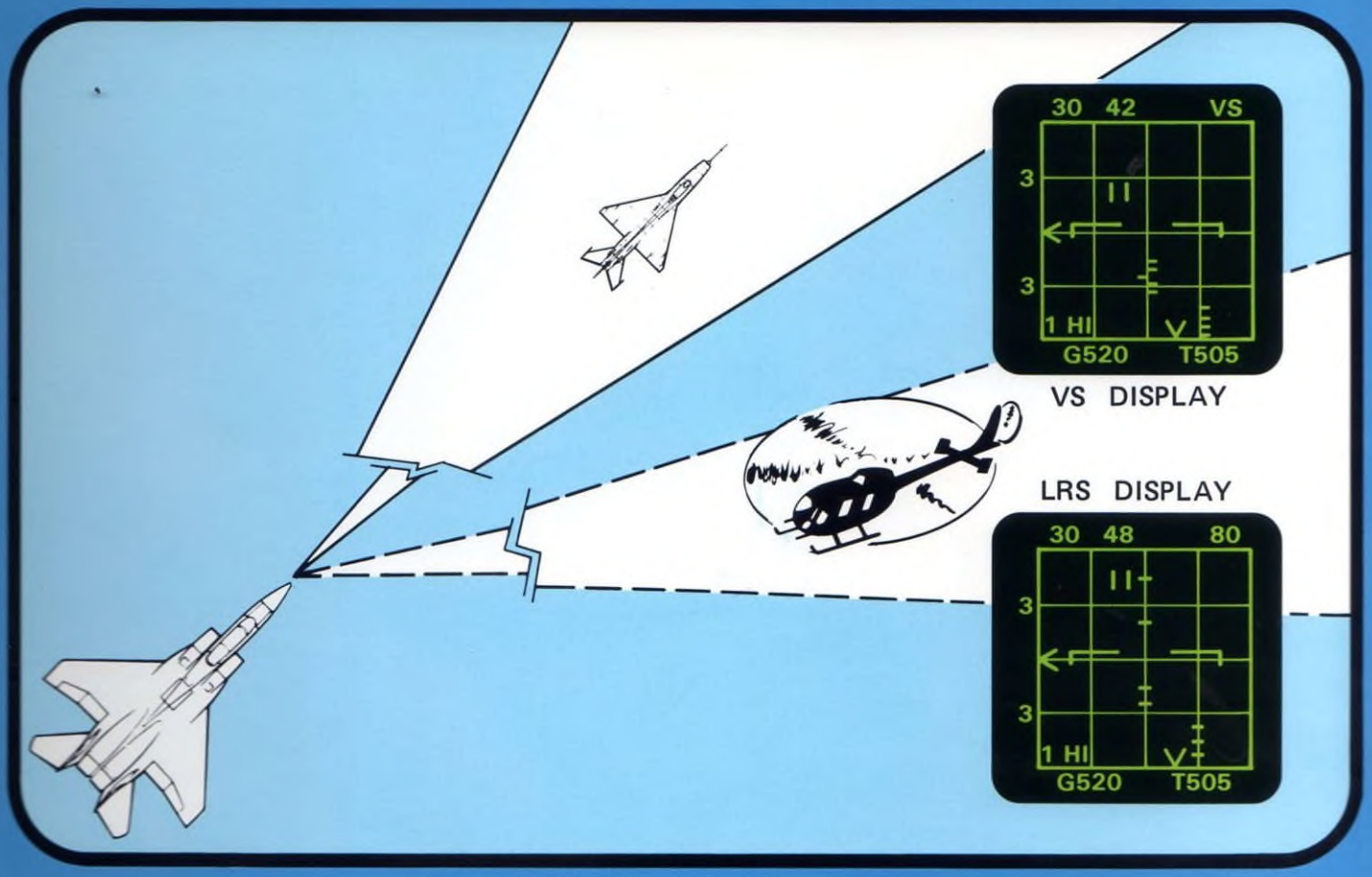
Pheno

In the case where the radar fails while airborne for whatever reason, it should be BIT checked while still airborne. Neglecting this, a BIT check by ground personnel simply clears all airborne failures from the flight, making it almost impossible for maintenance to duplicate a flight environment squawk.

A good rule to go by is: Always run an airborne BIT and record the matrix as soon after a radar problem as the mission permits. This procedure will allow complete testing and fault isolation by BIT in the environment of the failure and greatly aids the maintenance task.

Design

The APG-63 can perform an initiated BIT whenever directed to by the operator. Results are readily available for readout and recording.



Squawk

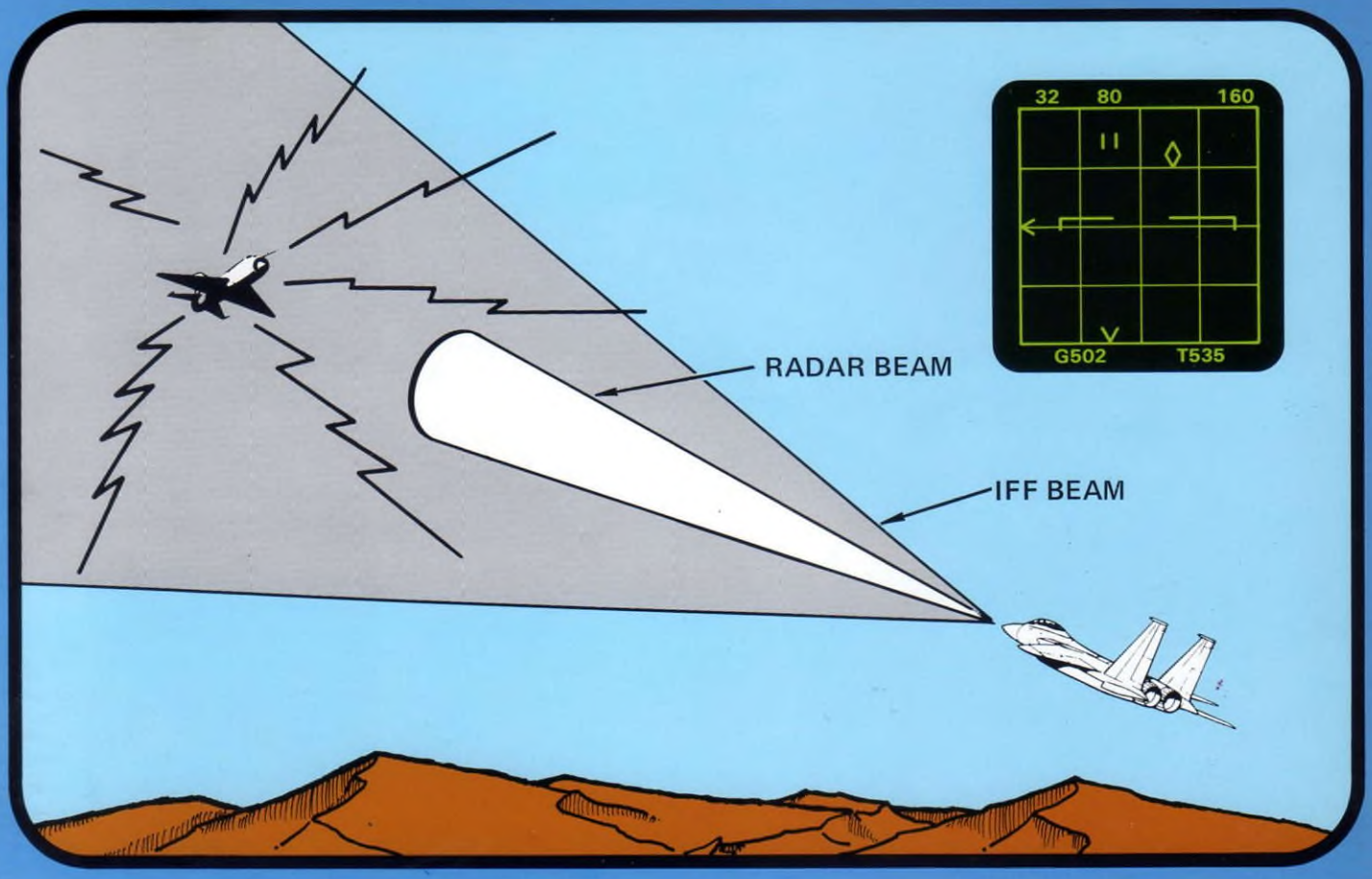
The range rate indicated a closing speed and I know the target was tail on.

Pheno

We know that the HPRF waveform cannot detect a tail aspect target return. It can, however, lock on and track jet engine modulation. If you suspect this, reject and relock using SRS or SS as MPRF acquisition will not encounter this problem.

Design

The HPRF doppler return of a tracked target can be modulated by internal or external engine components of the target (fans/props) creating erroneous velocity information.



Squawk *I had IFF returns, but never saw the target.*

Pheno IFF detections occur at longer ranges than radar detections.

Design It is normal for IFF to detect readily because the range capability of the IFF system exceeds that of the radar and the IFF antenna beam is very wide in elevation.

We Hope You'll Join Us Again Sometime...

Good Flying

HUGHES

HUGHES AIRCRAFT COMPANY

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